ESTIMATED PUBLIC BENEFITS OF IMPLEMENTING THE PROPOSED REVISIONS TO REGULATION 308

VOLUME I - REPORT

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VOLUME I - REPORT

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EXECUTIVE SUMMARY

This study identifies the air quality, health and environmental benefits expected from implementation of proposed revisions to Regulation 308. The study covers 96 contaminants emitted by over 3,500 establishments in 48 industries across Ontario. Benefits are estimated under five scenarios for implementation of the proposed revisions.

The public benefits of reduced contaminant emissions depend upon:

- the contaminant whose emissions are reduced;
- the change in concentration of that contaminant at each point;
- the population and environmental resources in the areas where concentrations are reduced; and
- the human health and environmental responses to the reduced concentrations.

The study is an ambitious attempt to grapple with a problem at the frontiers of industrial chemistry, health risk analysis and economics.

Data on estimated annual emissions by contaminant for each economic sector, under the present regulations and under the five scenarios for implementation of the proposed revisions to Regulation 308, were provided by a related study. The emissions data cover only 54 of the 96 contaminants.

The dispersion of those emissions is estimated by the new models developed by the Ministry of the Environment for use with Regulation 308. This allows us to identify the population and environmental resources exposed to emissions of each contaminant.

Reduced concentrations resulting from lower emissions due to implementation of the proposed revisions to Regulation 308 yield public benefits in the form of:

- lower risk of mortality;
- systemic health benefits;
- fewer exposures to above health threshold concentrations of contaminants;
- improved visibility;
- less materials damage; and
- smaller areas of agricultural land exposed to above threshold concentrations of contaminants.

Coverage of these benefits is incomplete because our knowledge of the effects of a contaminant is often limited. Possible benefits related to animal (domestic and wildlife) health, commercial forest areas, wilderness areas, aquatic toxicity, surface water and odour are not estimated due to data or methodological limitations. As a result, the benefits are understated.

In most cases the analysis is based on emissions from Regulation 308 Sources alone. This also tends to underestimate the benefits. Non-Regulation 308 source emissions are approximated for six contaminants, thus providing more accurate estimates of the benefits of the proposed revisions to Regulation 308 in those cases.

The annual reduction in mortality is estimated to be between 133 and 372 persons per year depending upon the implementation scenario. The economic value of this reduction in mortality is estimated to be between $0.3 and $2.6 billion annually.[1] Reduced

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1 All monetary amounts are 1986 Canadian dollars.

emissions of sulphur dioxide are the source of most of this benefit.

Systemic health benefits for which an economic value can be calculated are due primarily to reduced hospitalization. These benefits are estimated at $0.004 to $0.050 billion annually.

Currently, 11 contaminants exceed health threshold concentration levels in some area of the province. The proposed revisions to Regulation 308 eliminate, or significantly reduce, the population exposed to above-threshold concentrations of these contaminants. We have no basis for estimating an economic value for these reduced exposures.

With available information, improved visibility and reduced materials damage benefits can only be estimated for nitrogen oxides and particulate matter. The annual benefit of reduced materials damage ranges between $0.2 and $0.9 billion. The economic value of improved visibility varies between $1.2 and $4.2 billion annually. Eight of the contaminants are identified as being potentially harmful to plants. No agricultural areas are presently exposed to above threshold concentrations of these contaminants.

The total value of the public benefits for which an economic value has been estimated ranges between $1.2 and $4.0 billion annually for the least stringent implementation scenario. The most stringent implementation scenario yields benefits with an economic value of $3.3 to $7.7 billion per year.

The absence of a damage function does not mean there is no benefit and the lack of an economic estimate does not mean the benefit has no value. The figures presented above apply only to those few cases where public benefits can be quantified and associated economic values can be estimated.

The results provide a rough indication of the nature and magnitude of the public benefits attributable to implementation of the proposed revisions to Regulation 308. The results are defensible if used properly. They are broad approximations; not precise estimates. They are aggregate estimates; details relating to individual establishment or specific location are inexact. The analysis provides a good overview of a topic where previously we had no information. But considerable scope for refinement and enhancement remains.

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1.0 INTRODUCTION

1.1 What We Did

The Ontario Ministry of the Environment has proposed stricter regulation of air pollutant emissions. The DPA Group was commissioned to examine the public benefits of the proposed revisions to Regulation 308 under consideration by the Ministry. This is the report on that assignment.

The project was an ambitious attempt to grapple with a problem at the frontiers of industrial chemistry, health risk analysis and economics. The intent was to get an overview of the nature and magnitude of the public benefits attributable to implementation of the proposed revisions to Regulation 308. Despite data gaps and areas of uncertainty, the results provide aggregate estimates of the magnitude and insight into the nature of those public benefits. The methodology and data used are not accurate for individual establishments nor specific locations. The study provides a broad overview rather than detailed analyses.

The topic is large and complex. The public benefits of reduced contaminant emissions depend upon:

- the contaminant whose emissions are reduced;
- the change in concentration of that contaminant at each point;
- the population and environmental resources in the areas where concentrations are reduced; and
- the human health and environmental responses to the reduced concentrations.

This study was designed to cover all industrial point-sources coming under Regulation 308 in the entire province. Ninety-six different contaminants were analysed.

We identified the location of each source and estimated the quantity of each contaminant emitted by each source at present and under the proposed revisions to Regulation 308. The dispersion of each contaminant over the area around its source, at present and under the proposed revisions to Regulation 308, was modeled to calculate the change in contaminant concentration.

Next we identified the population and environmental resources in the areas of the reduced contaminant concentrations. The reduced concentrations of contaminants improve human health and reduce damage to the environment. The specific human health and environmental benefits due to lower concentrations of each of the 96 contaminants were identified. Where possible we quantified and estimated an economic value for these public benefits.

1.2 Limitations of the Study

This study is unique in the scope of its coverage. To our knowledge no previous study has covered so many different chemicals, such a wide geographic area, and such a variety of emission sources. Despite the broad scope, the study was constrained by a tight time schedule. As a result, we had to rely upon readily available secondary information for the analysis.

This project was an ambitious attempt to grapple with a large and complex problem under severe time constraints. The results provide an indication of the nature and magnitude of the public benefits of the proposed revisions to Regulation 308. Previously, these were unknown. It is important to remember that

the results are broad approximations; they provide direction but by no means all the answers.

The results are defensible, but there is scope for much refinement. We are careful to explain what we did at each step of the analysis, and why we approached the steps as we did. This shows the reader the problems entailed in the analysis, gives a sense of the uncertainties involved, and suggests directions for future refinement.

The methodology and data used in the analysis involve many uncertainties. The estimated emissions of specific contaminants by individual sources, for example, have wide margins of error. The locations of emission sources, the characteristics of these sources, the dispersion of emissions and the resource exposures are other sources of uncertainty. Probably the largest source of uncertainty is our extremely limited knowledge of the human health and other environmental responses to changes in exposure to contaminants. A study such as this can not reduce this source of uncertainty. The results are useful, even if only approximate, providing one recognizes the limitations. In particular, the results are not accurate for specific establishments and geographic areas.

The profile of emission sources in the province and the benefits associated with control of individual chemicals are of considerable interest. The study also provides a methodological framework which should prove extremely useful for further analysis and upgrading. It provides a context within which more detailed analyses and refinements can be undertaken.

1.3 Organization of the Report

The report is organised as follows. The core of the report is Chapters 2 to 5.

Chapter 2, Definition of the Problem, explains in more detail the purpose of the study, its relationship to the other studies undertaken at the same time, the definition of the problem and restrictions to the scope of the analysis.

Chapter 3, Analytical Approach, describes the steps we took to progress from the raw data we obtained, or were given, concerning emission sources, quantities emitted, dispersion of contaminants, human populations and environmental resources affected, and human health and environmental responses to reduced concentrations of chemicals, to calculate the public benefits.

Chapter 4, Results, presents the results of our analysis on a contaminant by contaminant basis. The specific benefits associated with reduced emissions of each contaminant are identified.

Chapter 5, Summary and Conclusions, summarises the results by category of benefits and implementation scenario, documents the uncertainties, and highlights areas for future research and refinement.

1.4 Appendices

The remainder of the report consists of appendices which discuss some of the analytical steps and data in more detail.

Appendix A, Economic Valuation of Benefits, explains how changes in air quality can be translated into dollar terms and documents the values selected for specific benefit categories.

Appendix B, Economic Sectors, gives an overview of each sector considered as a source of emissions in this study.

Appendix C, Regulation 308 Contaminants, profiles each of the chemicals we were asked to consider. These profiles give details of known or suspected effects on human health, agriculture, water, and natural ecosystems, and how the chemicals are presently regulated in Canada and in the United States.

Appendix D, Emissions Data, presents emissions data we were provided for each economic sector. These data had to be refined as described in Chapter 3 and Appendix E, and to be distributed across the individual source establishments.

Appendix E, Speciation Profiles, lists the chemical components of Volatile Organic Compound (VOC) and Particulate Matter (PM) emissions from each industry. The emissions data are in terms of total VOC's and PM. Since the benefits derive from reduced exposure to specific chemicals, these broad categories were disaggregated (speciated) into their constituent chemicals.

Appendix F, Dispersion Modelling, explains how the dispersion of emissions from point sources was modeled. The model calculates the ambient concentrations of a contaminant emitted by a specified source throughout a 48 km square area.

Appendix G, Spatial Analysis System, gives details of SPANS, the computer-based geographic information system we used in this assignment. This system was used to relate the geographic distribution of changes in contaminant concentration to the population and other environmental resources affected.

Appendix H, Exposure-Response Functions, describes the equations used to calculate specific benefits resulting from reduced contaminant concentrations.

Appendix I, Maps, contains the maps produced by SPANS. A few of these maps appear in Chapter 4.

Appendix J, Emissions Sources, is a list of the individual emission sources identified and used in the analysis.

2.0 DEFINITION OF THE PROBLEM

2.1 Background

The Ministry of the Environment published a discussion paper on air pollution regulation in Ontario in November, 1987.[1] That document identifies problem areas with the existing air pollution legislation and regulations. It goes on to propose reforms that would impose direct emission limits on all air pollution sources of any appreciable size.

As part of the review process for the proposed revisions to Regulation 308, the Ministry of the Environment commissioned four closely related studies to examine different aspects of these proposed changes.

The four studies, undertaken simultaneously, were:

- A study of the contaminant emissions and abatement costs by economic sector of the proposed revisions (Senes Consultants Ltd).

- A study of the monitoring requirements and associated costs of the proposed revisions (Senes Consultants Ltd).

- A study of the economic costs and consequences of implementing the proposed revisions (Informetrica Ltd).

- A study of the public benefits of implementing the proposed revisions (The DPA Group Inc.).

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1 Clean Air Program, Stopping Air Pollution At Its Source, Discussion Paper, Air Pollution-General Regulation, (Regulation 308), Ministry of the Environment, November 1987.

This study is closely linked to the first of the companion studies. That study estimates current emissions by contaminant for each sector, and emissions by contaminant for each sector under the proposed revisions to Regulation 308. Those estimates of current and potential emission levels are key inputs to the analysis undertaken here.

2.2 The Role of this Study

The purpose of this study is to identify the air quality, health and environmental benefits expected from implementation of proposed revisions to Regulation 308. Where possible, these benefits are quantified and valued in economic terms.

The assignment is large and complex. Key data, including the amount of each contaminant emitted by each source, are not available. The effects of reduced exposure are simply not known for many contaminants. Yet insight into the benefits of reduced air pollution is essential to a careful assessment of the proposed revisions to Regulation 308.

Despite the large data gaps and areas of uncertainty, this analysis provides insight into the benefits attributable to implementation of the proposed revisions to Regulation 308. The nature of the health and environmental benefits of reduced contaminant emissions and their geographic distribution across Ontario are documented. The contaminants and sources that will contribute most to these benefits are identified. The data gaps and uncertainties point to areas for further investigation.

2.3 Definition of the Problem

The problem to be analysed is shown in Exhibit 2.1. It shows a source of contaminant emissions governed by the proposed revisions to Regulation 308. These are almost all building sources.

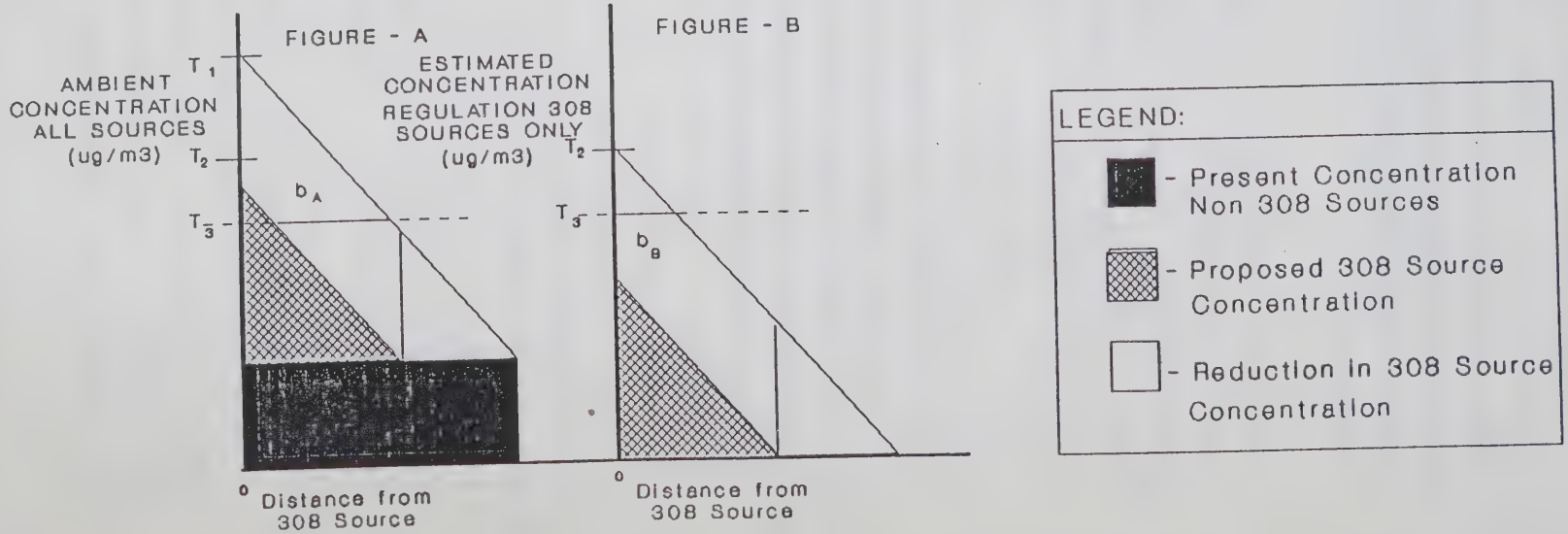
For most contaminants there are other emission sources that would not be governed by Regulation 308. These include sources such as automobiles, forests (a major source of some types of hydrocarbon gases), sources governed by other regulations, and emissions from other jurisdictions that enter Ontario.

The sources of most contaminant emissions are industrial park type buildings. Emissions from such sources are dispersed over an area of less than 25 km radius. Hence, the concentration of a contaminant at any point is largely determined by the dispersion of emissions from sources in the surrounding area. The effects of a contaminant on humans and environmental resources depend on the ambient concentration (the concentration of emissions from all sources) to which they are exposed.

The proposed revisions to Regulation 308 will reduce the emissions from the sources to which they apply. The lower emissions from these sources will reduce the ambient concentration in the surrounding area, assuming that emissions from non-Regulation 308 Sources do not change.

The change in ambient concentration can be estimated from the change in emissions from Regulation 308 Sources. However, the level of ambient concentration of a given contaminant can not be determined without knowing the emissions from all non-Regulation 308 Sources. They are usually not known.

EXHIBIT 2.1: THE ANALYTICAL PROBLEM



2.4 Determination of the Benefits of Reduced Concentrations

The benefits of a lower ambient concentration depend upon the specific contaminant, the resources it effects, the resources present in the area where the air quality is improved, and the nature of the relationship between contaminant concentration and damages.

The relationship between a reduction in ambient concentration and human health or other environmental benefits usually takes one of two forms. The benefits may be a function of the change in concentration. Alternatively the benefits may be a function of the level of concentration in the sense that there may be no observable effects for concentrations below a specific threshold value.

If the benefits are due to the change in ambient concentration, it is not necessary to know the concentration due to non-Regulation 308 Sources. The benefits can be estimated from the change in concentration due to emissions from Regulation 308 Sources alone. This can be seen in the lower panel of Exhibit 2.1. Figure A shows the ambient concentration due to all emission sources at various distances from a specific Regulation 308 Source. The change in concentration due to implementation of the proposed revisions to Regulation 308 is shown as Δ . Figure B shows the ambient concentration due to Regulation 308 Source emissions only as one moves away from the same Regulation 308 Source. The change in concentration due to implementation of the proposed revisions to Regulation 308 is again denoted by Δ and is equal to the change that occurs in Figure A.

Where the benefits are due to reduced exposure to concentrations above a threshold level, it is necessary to know the contribution of non-Regulation 308 Sources to accurately estimate the benefits

of the proposed revisions to Regulation 308. The lower panel of Exhibit 2.1 illustrates this point as well. Assume that the threshold level above which damage occurs is between T_1 and T_2. Figure A shows that there are areas of above-threshold exposure when all sources are considered. It also shows that implementation of the proposed revisions to Regulation 308 would eliminate those above-threshold exposures. Thus, implementation of the proposed revisions would yield a public benefit.

If the contribution of non-Regulation 308 Sources is not known, as in Figure B, there is no apparent benefit due to implementation of the proposed revisions when the threshold level is between T_1 and T_2. Not knowing the contribution of non-Regulation 308 Sources causes us to underestimate the benefits of the proposed revisions by assuming there is no benefit, when a public benefit does in fact occur.

If the threshold level above which damage occurs is below T_2 public benefits can be estimated from the concentrations due to Regulation 308 Source emissions, although those estimates are not accurate. To understand this, assume that the threshold level is T_3. When all emission sources are considered (Figure A) implementation of the proposed revisions to Regulation 308 yields a benefit over the area b_A. Revising Regulation 308 would eliminate above-threshold concentrations over the area b_A. That is the correct estimate of the public benefit due to revision of the Regulation.

If the contribution of non-Regulation 308 Sources is not known (Figure B), the benefit of the proposed revisions is estimated to yield a benefit over area b_B. Note that $b_B \leq b_A$ as long as the Regulation 308 Source emissions are not eliminated entirely. The fact that $b_B \leq b_A$ suggests that b_B can be considered a lower bound estimate of b_A. In other words, it suggests that the benefits estimated on the basis of Regulation 308 Source

emissions alone (b_B) can be considered a lower bound estimate of the true public benefit (b_A).

The foregoing conclusion is deceptively misleading. The areas where the benefits occur (b_A) and are estimated to occur (b_B) are different and at different distances from the Regulation 308 Source. The estimated benefit (b_B) is clearly not an accurate indicator of the location of actual benefit (b_A). If the population or environmental resource is more densely concentrated in the estimated benefit area (b_B), then the reduced above-threshold exposures calculated for that area could exceed the actual benefits of reduced above-threshold exposures in area p_A. In general, however, we believe that use of concentrations due to Regulation 308 Source emissions alone provides a lower bound estimate of the magnitude of the public benefits due to fewer above-threshold level exposures.

2.5 Basic Aspects of the Problem

The basic aspects of the problem are to:

- identify the contaminants to be studied;
- identify the locations of the Regulation 308 Sources of each contaminant;
- calculate the emissions by each source at present and under the proposed revisions to Regulation 308;
- determine the dispersion of emissions from each source at present and under the proposed revisions to Regulation 308;
- determine the contribution of non-Regulation source emissions to the ambient concentration at each point if possible;
- determine the human health and other resource benefits of reduced concentrations of the contaminant;
- determine the distribution of population and/or environmental resources in the areas where contaminant concentrations are reduced;

- calculate the benefits of reduced emissions of the contaminant by Regulation 308 Sources; and
- estimate the economic value of these benefits, if possible.

It is easy to see that with almost 100 contaminants and approximately 3,500 Regulation 308 Sources across the province the problem is large and complex.

2.6 Assumptions and Restrictions to the Scope

To make the analysis manageable it was necessary to make a number of assumptions and impose several restrictions on the scope of the study.

- First, the analysis is restricted to changes in emissions attributable to the proposed changes to Regulation 308. Other initiatives of the Ministry of the Environment may affect some of the same contaminants and sources. The acid rain initiative is a particular example. Any emission reductions due to those other initiatives are excluded from this analysis because they are not benefits attributable to the proposed changes to Regulation 308.

- Emissions from new or expanded public facilities are excluded because such facilities come under the environmental assessment review process. The consequence of such reviews is that public facilities are expected to meet the highest environmental standards available. Changes in emissions of such facilities are due to the review process rather than proposed revisions to Regulation 308.

- Long range transport of air pollutants is excluded from the analysis. The principal contaminants involved in long range transport and the major sources of those contaminants are

covered by the acid rain initiative rather than the proposed revisions to Regulation 308.

- Ozone, a very important pollutant, is excluded from the analysis because its chemistry is too complex to model here. Ozone itself is not emitted from industrial plants. It is a "secondary pollutant", formed in the atmosphere from volatile organic compounds and nitrogen oxides. These interactions are not yet well understood scientifically. Ozone is also subject to long range transport, so the effects may occur far from the point of precursor emissions.

- The analysis is limited to a single year. It simply is not feasible to forecast specific plant locations, plant sizes, population distribution, agricultural activity, forest cover, etc. into the future.

- Reduced emissions outside Ontario (e.g., Quebec) resulting from implementation of the proposed revisions to Regulation 308 are not counted because they are not benefits to Ontario.

- We assume that there are no chemical interactions among the contaminants emitted. The scientific data on the interactions of contaminants is so sparse that no other approach is feasible. Emissions of a given contaminant are simply converted to concentrations at various distances from the source. If chemical reactions occurred, the concentrations would be higher or lower than those resulting from the emissions alone.

- Benefits of reduced emissions are assumed to be additive. If lower acrylonitrile emissions and reduced asbestos emissions both result in lower cancer mortality we assume

that the survivors are not double counted. The available information does not permit any other assumption.

- The study deals with exterior air quality. No attempt is made to address changes in indoor air quality either at work places where contaminants are emitted, or in residential areas where they might be deposited.

2.7 Contaminants Considered

The Discussion Paper that outlines proposed revisions to Regulation 308 includes an appendix that defines proposed ambient air standards.[2] That appendix lists 244 proposed standards. There are multiple standards for some contaminants based on different averaging times, seasons and other factors. In total about 234 different contaminants are covered. That number is too large to be manageable in this study.

A list of 93 contaminants was identified in consultation with the Ministry of the Environment for the purposes of this analysis. Three more contaminants were added later. The final list of the 96 "Regulation 308 Contaminants" is presented in Exhibit 2.2 (see page 133). It includes ten contaminants not included in Appendix 2 of the Discussion Paper.

2.8 Economic Sectors

We defined a list of economic sectors suspected to emit one or more of the 96 Regulation 308 Contaminants. This was done in consultation with the Ministry of the Environment and the

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2 Clean Air Program, Stopping Air Pollution At Its Source, Discussion Paper, Air Pollution-General Regulation, (Regulation 308), Ministry of the Environment, November 1987, Appendix 2.

consultants responsible for the related studies. These economic sectors are listed in Exhibit 2.3 (see page 135).

The starting point was the activities or processes, such as whey drying, painting of automobiles, or incineration of hospital wastes, believed to generate one or more of the contaminants of interest. However, since much of the technical and economic information is collected and organized on the basis of Standard Industrial Classification (SIC) definitions, the activities and processes of interest had to be linked to SIC categories. In many cases the correspondence is very good; cement production and petroleum refineries, for example. In other sectors the analysis is limited to part of the SIC industry definition: for example, open pit mines are distinguished from underground operations and fossil fuel fired generating stations are separated from other generating stations.

In a few cases, such as hospital, municipal and industrial incinerators, where the SIC classification was not very useful, we simply defined the sector to suit our purposes.

The result is a structure that closely approximates the emission sources of concern and also allows us to draw upon standard statistical sources for data.

2.9 Regulation 308 Implementation Scenarios

Five implementation scenarios for the proposed revisions to Regulation 308 are defined in terms of level of control technology and implementation date. The proposed revisions to Regulation 308 identify three levels of control technology that can be applied to different categories of contaminants. They are:

- LAER, or Lowest Achievable Emission Rate (the most stringent form of control);

- BACT, or Best Available Control Technology; and
- NSPS, or New Source Performance Standards (the least stringent control).

The Discussion Paper does not define these levels of control explicitly, but suggests that the corresponding control technology in the United States provides a useful reference point. Senes defined the specific control technologies and corresponding emissions that form the basis for this analysis. The interested reader is referred to their report for further details.

The implementation scenarios specify the level of control to be applied to each category of contaminants. Exhibit 2.4 shows the proposed level of control for each contaminant type by scenario. There are more LAER controls in Scenario B where stringent emission controls are considered, and more NSPS controls under the less stringent control scenario (Scenario C).

Scenario D is defined using two levels of control rather than three levels as assumed in Scenario A. In practice Scenarios A and D are the same. The contaminants governed by less stringent controls in Scenario A are usually found in emission streams to which more stringent controls must be applied, so they are also controlled at this more stringent level. Scenario E is the same as Scenario A except for the implementation schedule. The estimated emissions provided by Senes for Scenario E correspond to the first phase of the implementation schedule for Scenario A.

These control scenarios were developed in consultation with the Ministry of the Environment. Information on the different levels of control technology is available in the MOE Discussion Paper. The Senes report specifies the control technology assumed for each contaminant group and industry sector. It also estimates the resulting emissions by contaminant for each scenario.

EXHIBIT 2.4: PROPOSED SCENARIOS

SCENARIO	A Initial	B More Stringent	C Less Stringent	D 2 Tier
CONTAMINANT GROUP				
Volatile Organic Compounds				
Chlorinated	LAER	LAER	BACT	LAER
Aliphatics	NSPS	BACT	NSPS	BACT
Aromatics	BACT	LAER	NSPS	BACT
Esters/Alcohols/ Esthers/Aldehydes/ Ketones	BACT	LAER	NSPS	BACT
Mercaptans	NSPS	BACT	NSPS	BACT
Particulates Associated				
Organics	LAER	LAER	BACT	LAER
Metals	LAER	LAER	BACT	LAER
Other Particulates	BACT	LAER	NSPS	BACT
Semi-Volatile Organics	BACT	LAER	NSPS	BACT
Pesticides	BACT	LAER	NSPS	BACT
Corrosives				
Acids	BACT	LAER	NSPS	BACT
Bases	BACT	LAER	NSPS	BACT
Other	BACT	LAER	NSPS	BACT
Other	BACT	LAER	NSPS	BACT

IMPLEMENTATION

SCENARIO	A,B,C,D	E*
New Facilities	1989	1989
Existing Facilities Contaminant Group:		
LAER	1994	2004
BACT	1994	2009
NSPS	1999	2014

* Same as Scenario A except for implementation schedule.

2.10 Limitations of the Data

The exercise was severely constrained by available information. The short time available for the study restricted us to readily accessible data.

- Data on current and projected emissions of each contaminant by establishment are not available and had to be estimated for 96 contaminants emitted by 2,185 industrial establishments, 1,200 dry cleaners, and 200 restaurants with charcoal barbecue facilities across Ontario.

- Data on the concentrations due to emissions from non-Regulation 308 Sources are extremely limited. Yet these are essential to the determination of health and environmental effects related to the ambient concentration of a specific contaminant.

- Health and environmental effects associated with specific ambient concentrations are uncertain for all listed chemicals and unknown for many.

- While the principles of economic valuation of public benefits are widely accepted, empirical estimates are lacking for many benefit categories and subject to wide variations for other benefits.

Many approximations, estimates and assumptions are needed to complete the analysis. An analysis of the impacts of such a large number of facilities and contaminants would not be feasible otherwise.

3.0 ANALYTICAL APPROACH

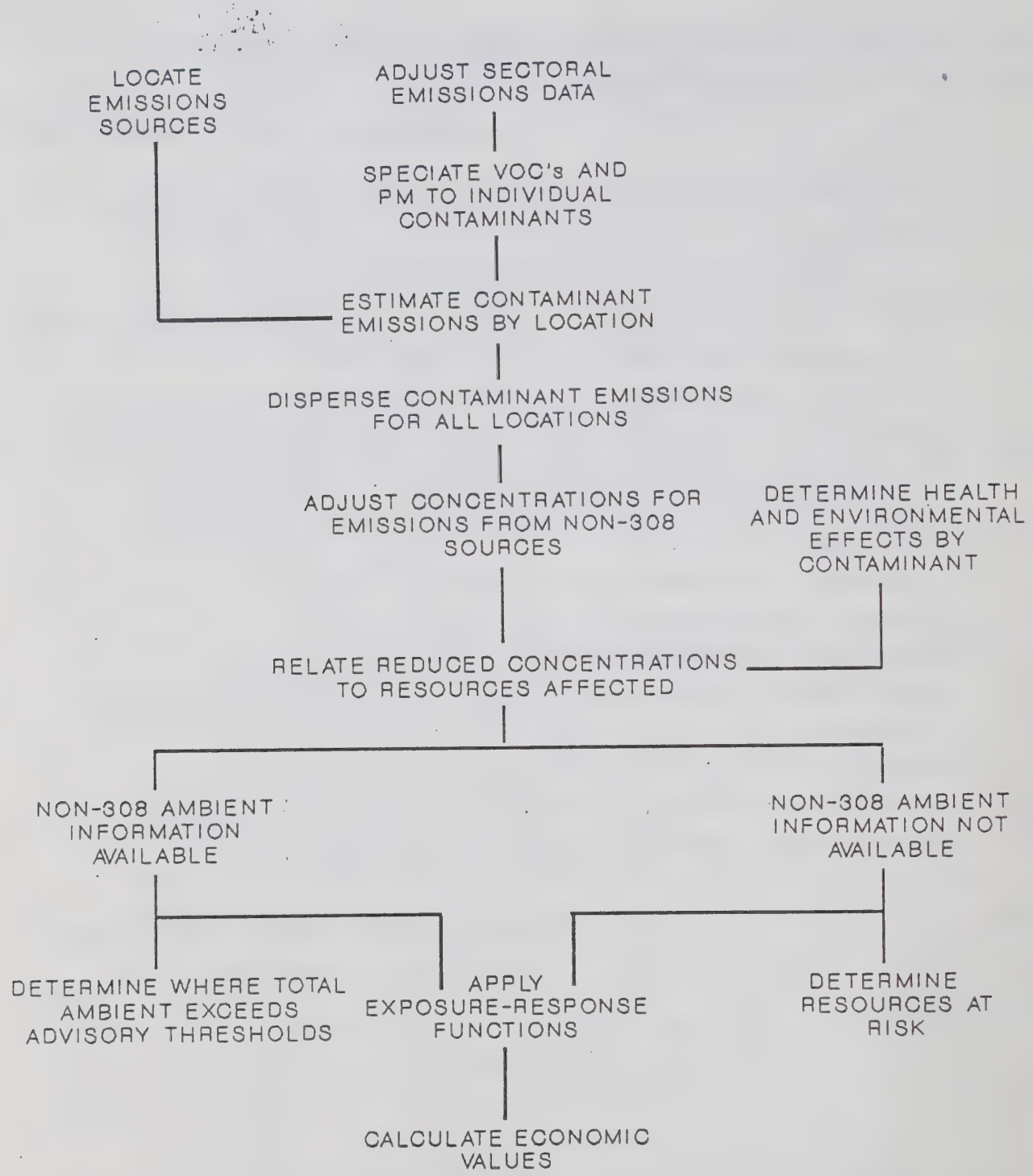
3.1 Overview

An overview of the steps in the analysis is provided in Exhibit 3.1. Briefly the steps are to:

- identify the locations of the Regulation 308 Sources of each contaminant;
- adjust the sectoral emissions data received from Senes Consultants;
- speciate the VOC and PM emissions by sector;
- calculate the emissions by each source at present and under the proposed revisions to Regulation 308;
- determine the dispersion of emissions from each source at present and under the proposed revisions to Regulation 308;
- determine the contribution of non-Regulation source emissions to the ambient concentration at each point, if possible;
- determine the human health and other resource benefits of reduced concentrations of the contaminant;
- determine the distribution of population and/or environmental resources in the areas where contaminant concentrations are reduced;
- calculate the benefits of reduced emissions of the contaminant by Regulation 308 Sources, if possible; and
- estimate the economic value of these benefits.

The balance of the chapter discusses these steps in more detail. Further information on some of the steps is provided in the appendices.

EXHIBIT 3.1: ANALYTICAL APPROACH



It is important to appreciate that the analytical steps taken varied according to the data available on:

- emissions of the contaminant in question from Regulation 308 Sources;
- ambient concentrations of the contaminant from non-Regulation 308 sources; and
- health and other effects of the contaminant.

Most significantly, ambient concentrations of contaminants from non-Regulation 308 sources were only available for a few contaminants. This meant that some steps described could not be undertaken (i.e., those relating to determination of ambient concentrations from all sources and the changes in these concentrations attributable to reduced emissions from Regulation 308 Sources).

3.2 Locations of Sources of Regulation 308 Contaminant Emissions

As indicated in Exhibit 2.3, the analysis covers 44 economic sectors or subsectors with 2,185 industrial establishments, 1,200 dry cleaning establishments and 200 restaurants that barbecue with charcoal. The analysis requires that the location of each source be specified. The economic sector of each source must be known so that the correct emissions profile can be assigned. An indicator of the size of the source must also be obtained, so that the estimated emissions for the sector can be apportioned across the establishments in that sector.

3.2.1 Data Sources

We used two principal sources to identify locations and sizes of establishments in each sector. These sources are:

- the Made in Ontario data base compiled by the Ontario Ministry of Industry, Trade and Technology; and

- a listing of establishments purchased from Statistics Canada.

The Made in Ontario data base includes the firm name and address as well as the 1980 SIC code and level of employment. The Statistics Canada listing includes the firm name, municipality, 1980 SIC code and employment size category. Employment was estimated as the mid-point of the size category.

We took care to eliminate entries that appeared in both sources. Given duplicate entries, we used the more specific information from the Made in Ontario data base. Head office locations with no associated production facilities were also eliminated. Finally, we compared the list of establishments and profile of each sector with profiles prepared for other purposes to ensure that our list was reasonably complete.

A definition of each economic sector, the data sources used, the contaminants emitted, the method of allocating sector emissions to individual establishments and a map showing the locations of the establishments is attached as Appendix B. A list of the individual establishments is provided in Appendix J.

3.2.2 Locations

The Made in Ontario establishments were plotted on the spatial analysis system at the postal code centroid. The Statistics Canada establishments were plotted at the census sub-division centroid for the municipality.

To facilitate the analysis, a four kilometre grid was created for the entire province. Each establishment was moved from the

postal code or census sub-division centroid to the nearest grid point (less than 2 km). This is within the margin of error associated with the original -- postal code or census sub-division centroid -- location. In some cases, notably in the Toronto area, this system led to high numbers (over 10) of establishments located at the same grid point. We contacted the largest plants in these concentrations to obtain a more accurate positioning for them. Where appropriate, the larger firms were repositioned to other points on the grid.

The locations of the 2,185 industrial establishments are shown in Exhibit 3.2. The map also shows population density by census sub-division. It is immediately evident that the establishments are concentrated in the more populous parts of the province. This suggests that the principal benefits of reduced emissions will relate to human health.

3.3 Adjustments to Sectoral Emissions Data

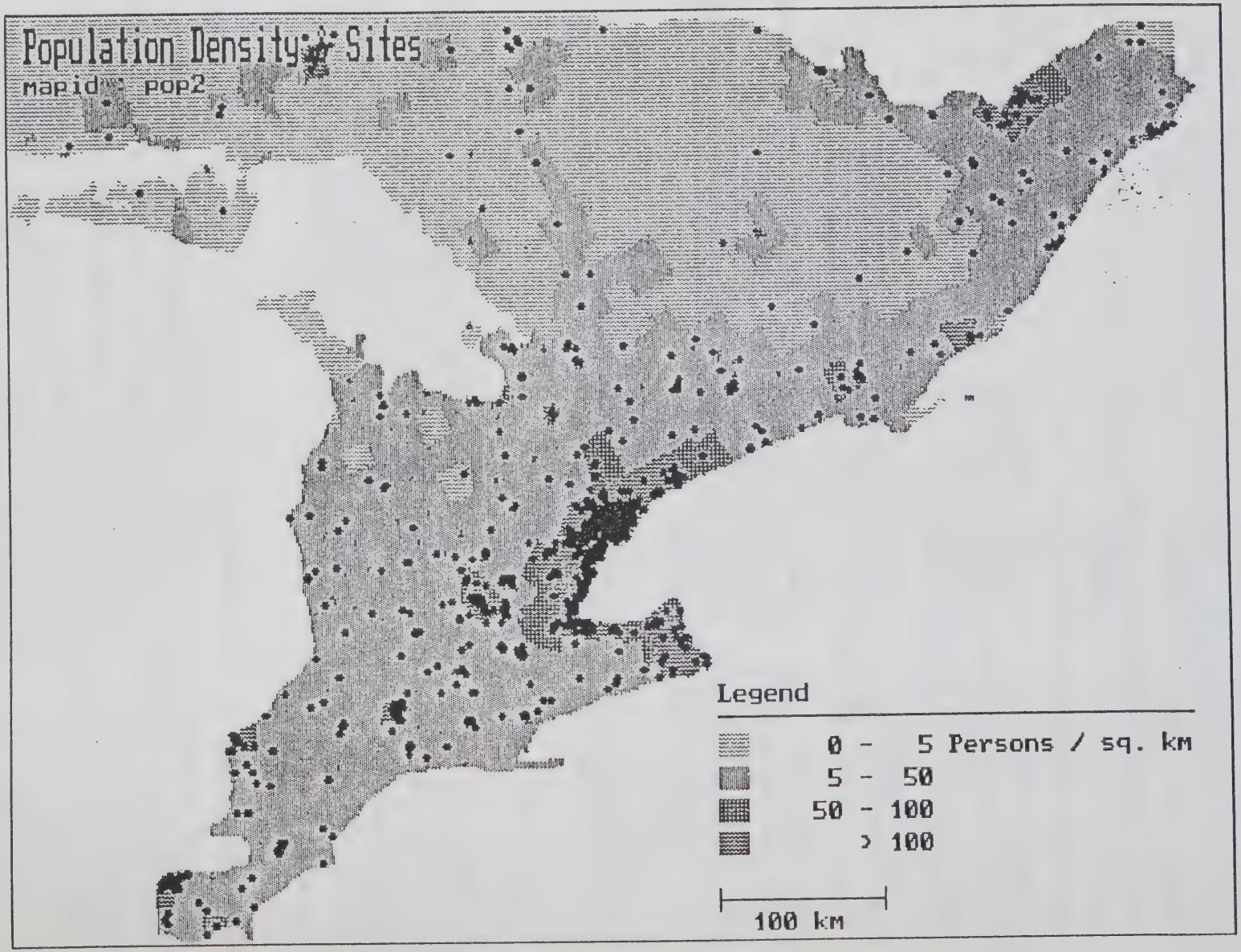
3.3.1 Senes Emissions Data

The emissions data on which this report is based were supplied to us by Senes Consultants Ltd. The data set we were given is reproduced in Appendix D. The interested reader is directed to the Senes report for a discussion of the derivation of their emissions estimates.

Senes provided us with estimated annual emissions by contaminant for each economic sector under the present regulations and under the five scenarios for implementation of the proposed revisions to Regulation 308. We had to adjust to these data in several ways to meet the needs of our analysis:

- the capacity utilization assumed had to be changed;
- the emissions rate had to be changed from tonnes per year to grams per second;

EXHIBIT 3.2: LOCATIONS OF INDUSTRIAL ESTABLISHMENTS AND POPULATION DENSITY



- the composite categories of PM and VOC's had to be disaggregated into their constituent chemicals; and
- the emissions had to be apportioned among the individual sources in the sector.

These adjustments are described below.

3.3.2 Capacity Use Assumptions

The contaminant emissions estimated by Senes assumed operation either at the rated capacity level (i.e., potential full production) or at the current level of capacity use (i.e., actual production). Benefits derive from changes in exposure. The change in exposure must be calculated from actual emissions. Hence, we based our analysis on emissions at actual or normal levels of capacity utilization. Senes provided us with information on their capacity assumptions by SIC. We converted all contaminant emissions from full to actual production levels where necessary.

For industries where no production level information was provided, we used the 1984 to 1986 average yearly level of capacity use available from Statistics Canada's Capacity Utilization Rates in Canadian Manufacturing. The Statistics Canada data were used for the allied paper products industries, the chemical fertilizer industry, the paint and varnish industry, the adhesives industry or for the chemical products industry (not elsewhere classified). Capacity utilization is not relevant for dry cleaning establishments and restaurants.

3.3.3 Conversion of Emission Rate

To be consistent with the dispersion model, we needed to convert contaminant emissions from tonnes emitted on a yearly basis to

assume that all establishments operate 24 hours per day for 365 days per year.

Conversion of the contaminant emission rate involved the conversion of tonnes to grams (multiply by 1,000,000) and dividing by the number of seconds an industry operates per year (365 operating days per year x 24 hours per day x 3,600 seconds per hour = 31.536 million). Thus, contaminant emissions expressed in tonnes per year are converted to grams per second by dividing by 31.536.

In principle it is possible to designate each sector or establishment as normally working one, two or three shifts per day. The dispersion model could then be run with emissions restricted to the working hours. To calculate the annual average ambient concentration an emission rate of zero would be assumed during non-operating hours.

In our judgement the annual average ambient concentration calculated in that manner differs little from the annual average ambient concentration calculated under the assumption that the establishment operates continuously. To capture any differences of this sort would involve three times as much dispersion modelling effort. That extra effort can not be justified as long as the effects are being assessed from annual average ambient concentrations.

3.4 Speciation of PM and VOC's to Constituent Chemicals

3.4.1 Speciation of PM and VOC's

One of the challenges in this project was to disaggregate PM and VOC's emissions into their individual chemical constituents. These broad categories include dozens (PM) or hundreds (VOC) of different chemicals.

Reduced emissions of particulate matter, regardless of the composition, can yield health (respiratory problems, eye irritations etc.) and other (soiling, visibility reduction) benefits. But most health and environmental benefits derived from reduced emissions of PM's and VOC's result from lower concentrations of specific chemicals. Thus, the composition of the VOC and PM emissions must be determined so that the changes in emissions of specific chemicals can be examined.

The only source of detailed data on the composition of VOC's and PM's is the United States Environmental Protection Agency's (EPA), National Emissions Data System (NEDS). In the NEDS data base each U.S. SIC is divided into processes which are regarded as sources of emissions and are assigned a unique Source Classification Codes (SCC). Profiles of PM and VOC emissions are available from NEDS by SCC.

To use the SCC information on PM and VOC composition we needed to:

- select the SCC's that correspond to each of the Canadian industries or industry segments covered by this study;

- ensure that the SCC's selected correspond to the processes and emissions estimated by Senes. In some industries this meant that we had to adjust for different boiler fuel use by Ontario and U.S. firms; and

- aggregate the SCC profiles of PM's and VOC's into profiles corresponding to the Canadian SIC codes covered by this study.

Our approach to each of these steps is documented in Appendix E.

The PM and VOC speciations for the Canadian SIC codes used in this analysis are also provided in Appendix E.

3.4.2 Non-Regulation 308 Chemicals

The profiles break down the PM and VOC emissions into their constituent chemicals. Some of those constituent chemicals are Regulation 308 Contaminants. Others are not on the list of 96 chemicals we were asked to consider. Each profile shows the percentage contribution of each Regulation 308 Contaminant and a percentage for "other" chemicals making up the balance of the profile.

This "other" category typically accounts for most -- usually over 60 per cent -- of the PM and VOC emissions in a sector. The relatively large size of this "other" category raised the concern that potentially harmful contaminants were being overlooked. To allay this concern we provided a list of all VOC and PM chemicals on the NEDS database to the Ministry of the Environment for review. The Ministry was satisfied that the list of contaminants originally specified identified the chemicals of concern. However, this review did lead to the addition of three chemicals to the list of contaminants.

Thus, the "other" category can be considered to consist of relatively harmless chemicals. The steps taken to reduce emissions of the more hazardous chemicals in the VOC and PM streams will have the effect of lowering emissions of these more benign constituents as well at no additional cost. Because of the relatively benign nature of these "other" chemicals no benefits are deemed to be derived from their curtailment.

3.5 Individual Establishment Emissions

Emissions by a given establishment are estimated from the total emissions for the sector using a measure of the size of the facility. Total emissions for the sector are apportioned among the individual establishments in the sector on the basis of the selected measure of size, usually employment. All restaurants, dry cleaning establishments, poultry processing plants, mobile asphalt paving plants and different categories of waste disposal facilities are assumed to be of equal size. In the electric power generation sector, capacity is used to apportion the emissions. However, employment is the most widely used indicator of establishment size.

The assumption that emissions per employee are equal for all establishments in a given sector is obviously an approximation. Employment is the only readily available indicator of size and so is the only variable available for adjusting emissions to reflect establishment size. The allocation only occurs across establishments <u>within</u> a given economic sector. Thus, it reflects the likelihood that a plant with the same capacity as another, yet with a smaller workforce, will tend to be more modern and probably have better pollution control technology.

It is important to understand that the emissions for each establishment are crude estimates based on sector profiles and employment levels or other rough measures of size. They are <u>not</u> based on actual emissions inventories, nor monitoring data. The emissions profile for each sector reflects the pollution control measures in general use in that sector around the province. But the estimated emissions for an individual establishment do <u>not</u> reflect the specific pollution control measures that may be in place at that establishment.

The estimated reduction in emissions resulting from implementation of the proposed revisions to Regulation 308 are assumed to occur proportionally at every establishment in the sector. Each source is estimated to reduce its emissions from the "average" level for the sector to the level anticipated after implementation of the proposed revisions to Regulation 308. This assumption ignores the specific pollution control measures that may be in place. The implementation scenarios also assume that all establishments comply fully with the revisions to Regulation 308.

3.6 Dispersion Modeling

When a contaminant is emitted by a source, it is dispersed over the surrounding area. A dispersion model is used to calculate annual average ambient concentration attributable to the emissions from each source. The Ministry of the Environment's new dispersion models developed for use with Regulation 308 were used for the analysis.[3] These models cover an area 24 km in each direction from the source.

Climatic conditions and source characteristics play major roles in determining the concentrations at any point in the deposition area. The data sources used and assumptions made with respect to these variables are discussed in Appendix F and are summarized below.

3.6.1 Climatological Data

We used a "pre-public-release" version of the Ministry's GAS model for the dispersion modelling. The climatological data it requires as input include both surface observations and upper air

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3 Ontario Ministry of the Environment, 1987. Air Pollution Regulation 308, Appendix H: Air Pollution - General Regulation Modelling Proposals. 170 pp.

observations. There is no single station in the southern part of Ontario that has all of the information needed. The upper air data had to be obtained for U.S. and Quebec stations. They were then matched with surface observations for Ontario stations.

There are 32 hourly observing stations with sufficient record for climatological analysis. On the basis of similarity of weather conditions and proximity to Regulation 308 emission sources, fourteen were selected to represent weather conditions across the province. A representative year was identified, U.S. or Quebec upper air observations were matched to each station and the dispersion pattern calculated for each of these fourteen stations.

3.6.2 Emission Source Characteristics

Of the several thousand commercial emissions sources in Ontario subject to the proposed revisions to Regulation 308, by far the most numerous are building sources. Such sources are generally defined as sources from which fugitive emissions emanate or stack emissions emerge at elevations less than twice the height of the building.

To precisely model emissions from such sources the exact dimensions of the building and the stack must be known. For this study, no information was available on building or stack dimensions for any source. To estimate ambient concentration, each source was assumed to be a building of 7 m height and 100 m width with a stack of less than 14 m elevation, emitting pollutants at 0 velocity and at ambient exit temperature. Such a building is a typical "industrial park" source.

These source characteristic assumptions lead to very high ambient concentration uncertainties (i.e., order of magnitude) within 500 m of the source for buildings of other configuration.

Reasonable concentration estimates are achieved beyond 500 metres.

3.6.3 The Receptor Grid

The Ministry's program was used to generate a receptor grid network from 0 to 24 km of 2 km resolution. A finer grid of 500 metre and 1,000 metre grid points was added to permit better resolution in the near-source area where most of the impact of building sources is felt.

The source characteristic are assumed to be the same for all 14 patterns. An emission rate of one gram per second is used in each case. Since the model is linear with respect to dispersion, the calculated concentration at each grid coordinate is scaled by the emission rate for the specific source. For example, if the concentration at twelve kilometres due east of the source is calculated by the model to be 0.0158 micrograms per cubic metre and a given source emits a contaminant at a rate of five grams per second then the ambient concentration twelve km due east of that source will be 0.0790 micrograms per cubic metre.

The number of data points associated with a 2 km grid was unmanageable. The dispersion data were therefore adjusted to a 4 km grid. This is still within the margin of accuracy of the establishment locations.

The emissions of a contaminant were plotted as concentration values at the grid points around each source. Where emissions from two or more sources resulted in concentrations at the same grid point, the concentrations were added.

3.7 Ambient Concentrations

Most of the contaminants studied are also emitted by sources other than the specified industries. To calculate benefits it is sometimes necessary to know the change in the ambient concentration from all sources likely to occur as a result of implementation (in respect of some sources) of the proposed revisions to Regulation 308.

The only available source of information on the ambient concentration from all sources is monitoring information. To get the change in total ambient concentration for a contaminant resulting from implementation of proposed revisions to Regulation 308, it is necessary to relate monitoring results to predicted current emissions from Regulation 308 Sources. This gives an estimate of the ambient concentration attributable to non-Regulation 308 sources at each station. The estimated ambient concentration due to other sources will not change as a result of revisions to Regulation 308. It is assumed to remain constant for all implementation scenarios.

3.7.1 Monitoring Data

The Ministry of the Environment operates two networks of monitoring stations in Ontario. Stations on one network are located close to emission sources. Stations on the other network are designed to provide information about long range air pollution (for example, on acid rain) and are distributed across the province, so many are located in more rural areas. Locations of the monitoring stations are shown in Exhibit 3.3.

Of the 96 contaminants we were asked to consider, monitoring data are available only for cadmium, chromium, lead, manganese, nickel, sulphur dioxide, PM and total VOC's.

EXHIBIT 3.3: CONTAMINANT MONITORING NETWORKS

3.7.2 Use of Monitoring Data

The monitoring data are point data, i.e., ambient concentrations at the monitoring station locations. Using the dispersion modelling results, we determined the concentration of a monitored contaminant from Regulation 308 Sources at each monitoring station. We subtracted this concentration due to Regulation 308 Sources from the ambient concentration at the monitoring station. The result was a "residual" value for ambient concentration of the contaminant due to non-Regulation 308 Sources at each monitoring station.

Not surprisingly, this subtraction did not lead to uniform "residual" figures at all monitoring stations. This is partly due to the inherent inaccuracies in data and modelling of Regulation 308 Source emissions. It also reflects the fact that residual ambient values will vary according to where one is in the province. For example, the non-Regulation 308 Sources may be significantly different in rural and urban areas. For each contaminant, except sulphur dioxide, we added the maximum "residual" value from all monitoring stations to the estimated concentration due to emission from Regulation 308 Sources.

This maximum residual was added to the concentration due to Regulation 308 Source emissions under existing regulations, and under each implementation scenario for the proposed revisions to Regulation 308. The result was an upper bound estimate of total ambient concentration of the contaminant at all relevant points on the grid map for each implementation scenario. These ambient concentrations were compared to the health effect threshold values to determine the public benefits of the proposed revisions to Regulation 308. The population exposed to above threshold concentrations was reduced to nil under at least one scenario for cadmium, lead, manganese, and nickel, but not for chromium.

The above procedure could not be used with sulphur dioxide because many monitoring station readings for sulphur dioxide exceed the specified threshold. A number of the calculated residuals likewise exceed the specified health threshold. Using that maximum residual value raises the ambient concentration in all areas above the threshold under all scenarios. Instead we used several different values of the residual concentration for sulphur dioxide.

3.7.3 Particulate Matter and Volatile Organic Compounds in Ambient Air

Many monitoring stations measure aggregate PM and VOC's. VOC's form part of total reactive hydrocarbons (RHC's) in monitoring station data. It should be possible to speciate these PM and VOC readings in much the same way as we speciated emissions data (see Section 3.4 and Appendix E). However, we did not have sufficient data for non-Regulation 308 emission sources to do this in a way we could consider comparable to the speciated emissions data for Regulation 308 Sources. As a result the use of monitoring data to reflect the contribution of non-Regulation 308 Source emissions is limited to cadmium, chromium, lead, manganese, nickel and sulphur dioxide.

3.8 Contaminant Profiles

A full profile of the human health and environmental impacts of each contaminant is given in Appendix C. Based on a comprehensive literature search, each profile provides a summary of all that is readily known about:

- the contaminant's cancerous and systemic human health effects;
- current and proposed air quality standards for the contaminant in Ontario and the U.S.;

- ambient air levels (i.e., maxima) for the contaminant in various states in the U.S.A.;
- workplace advisory standards for the contaminant;
- the contaminant's effects on atmospheric visibility and odour;
- the contaminant's effects on animals, plants (phytotoxicity), and surface water ecosystems; and
- materials damage (e.g., soiling) that the contaminant may cause.

As the gaps in the profiles show, the data on impacts are far from complete.

The impacts expected for each contaminant are summarized in Exhibit 3.4 (see page 138). The best and most extensive information relates to human health impacts. This is reassuring in that the locations of Regulation 308 Sources suggest that human health will be one of the major benefits of reduced emissions.

3.9 Mapping Resources at Risk

3.9.1 The SPANS System

A vital tool for our analytical work was SPANS, or "spatial analysis system". SPANS' specialty is analysis and manipulation of spatial data. That is, data which relate to points or areas on maps, such as the distribution of natural resources or atmospheric pollutants across Ontario. It was ideally suited to this assignment.

Having determined the concentration of a contaminant at each grid point, it is necessary to relate that information to the resources at risk. There were over 15,600 points on our 4 km grid with an estimated concentration for at least one

contaminant under at least one scenario. A map of 4 km squares (16 km^2) was created with a grid point as the centroid of each square. The estimated concentration at the grid point was assumed to apply to the surrounding square.

The resources at risk include humans, crops, livestock, forests and surface water. Maps of these resources were purchased from various sources and converted to SPANS format. The system was then used to relate the change in concentration of a contaminant in a given square to the affected resource(s) in that square. By doing this for all 15,600 squares for each contaminant for all affected resources we were able to determine the public benefits associated with implementation of the proposed revisions to Regulation 308. Results of the analysis are presented as maps and summary tables.

3.9.2 Use of SPANS in the Analysis

Three different analyses were performed, depending upon the information available:

- estimated concentrations from Regulation 308 Sources only;
- estimated ambient concentrations from all sources; or
- an exposure-response function.

Further information on SPANS and how we used it in these analyses is provided in Appendix G.

In the first case, the dispersion pattern for the contaminant from Regulation 308 Sources only is superimposed on the appropriate environmental resource(s), usually population. The resources exposed to above threshold concentrations of the contaminant at present and under each implementation scenario are calculated. Since the contaminant concentrations are those due to Regulation 308 Sources only, the reduction in resources

exposed to above threshold concentrations is a minimum estimate of the reduction in the resources at risk due to implementation of the proposed revisions to Regulation 308.

For the six contaminants where the total ambient concentrations are available, the areas that exceed the threshold value for observable effects are plotted for the existing situation and for each scenario. The difference in the resources exposed to above-threshold levels of the contaminant is a measure of the public benefits of the proposed revisions to Regulation 308.

Where exposure-response functions are available, the change in exposure from the existing level is calculated for each grid square. This change is multiplied by the population of the grid square. These values are summed over all relevant grid squares. The aggregate values are used in the exposure-response function to calculate the estimated benefits of reduced emissions.

3.9.3 Change in Concentration by Scenario

The dispersion pattern is linear with respect to emission rate. In other words, if the emission rate is cut in half, the concentration at each point on the dispersion grid is halved. Thus, implementation of the proposed revisions to Regulation 308 does not change the area or population exposed to the contaminant whose emissions are reduced.

The concentrations are reduced at all points in the dispersion area, but the dispersion area itself, and hence the resources exposed, does not change. As a result we are unable to perform any analysis for those few contaminants where we do not have a threshold value. The population or other resource(s) exposed is the same under every scenario. The concentrations to which the resources are exposed are lower, but without knowing the effects

of different concentrations it is not possible to establish whether or not benefits arise.

3.10 Determination of Public Benefits

Owing to gaps in the data, we could not provide the same evaluation for all of the 96 Regulation 308 Contaminants. The following sections describe the analysis, according to the available data.

3.10.1 No Emissions Data

For many (42) contaminants no emissions were estimated. In those cases we were unable to evaluate the benefits of proposed changes to Regulation 308. The reasons why no emissions were estimated for these contaminants are given in Section 4.1.

3.10.2 Emissions But No Ambient Data

In most cases (48) we had estimated emissions for a contaminant, but no monitoring data to provide information about total ambient concentration. In these cases we were able to perform two analyses:

- the population or environmental resources exposed to contamination by emissions from Regulation 308 Sources under the various scenarios is compared with the current situation.

  We are able to show where changes in exposure would occur. These reduced exposures are not necessarily benefits. The ambient concentrations might be lower than the threshold values at which observable effects occur in all areas at present. In that case there are no benefits to reduced contaminant emissions. This leads to the second analysis.

- the population or environmental resources exposed to contamination by emissions from Regulation 308 Sources under the current situation and each implementation scenario is compared to the threshold value at which observable effects occur.

  If the current emissions from Regulation 308 Sources do not exceed the threshold, no further conclusions can be drawn. If the threshold is exceeded, the reduction in population or environmental resources exposed to above threshold values of the contaminant is a minimum estimate of the public benefit of the proposed revisions to Regulation 308.

3.10.3 Ambient Data Available

In the case of six contaminants we were able to use monitoring data to estimate the total ambient concentration. As described in Section 3.7.2 the monitoring data were used to calculate a residual concentration due to non-Regulation 308 sources at each station. The maximum residual value was then added to the estimated concentration due to Regulation 308 Source emissions under all scenarios. If the current ambient concentrations do not exceed the threshold value, no public benefits are attributable to the reduced emissions resulting from implementation of the proposed revisions to Regulation 308.

If the ambient concentration exceeds the threshold, the reduction in population or other resources exposed to above threshold values is an upper bound estimate of the public benefit of implementation of the proposed revisions to Regulation 308.

The threshold value is usually equal to the Ministry of Environment Standard proposed to be established under Regulation 308. It is important to remember that these standards

are of the often based on very limited data. Some MOE standards differ very considerably (in some cases conservatively, in others liberally) from comparable U.S. standards.

3.10.4 Exposure-Response Relationships

The relationship between exposure to a contaminant and the consequent damage is called an exposure-response function. These relationships, where available, are included in the contaminant profiles in Appendix C and, more explicitly, in Appendix H.

Exposure-response functions are available for cancer for many contaminants. Functions are also available for non-cancer health effects for nitrogen dioxide, sulphur dioxide and particulate matter. Visibility effects and materials damage functions are available for nitrogen dioxide and particulate matter.

The absence of an exposure-response function does not mean that health or other effects will not occur.

3.11 Overall Valuation

How should the effects of reduced emissions be valued? A detailed discussion of this subject is provided in Appendix A. In essence the effects are valued by determining how much society would be prepared to pay to avoid one death, one asthma attack, and so on.

Economic valuation of public benefits such as a reduction in the risk of death, improved visibility, lower materials damage and higher agricultural yields is in its infancy. Economists have worked on some topics such as the value of a statistical life but many more remain poorly investigated or completely untouched.

Economic values for a reduced risk of death and various health benefits are given in Exhibit 3.5. The values are drawn from American literature. In the case of the value of a statistical life this is because most of the available studies relate to the United States. In the case of the other health benefits, American estimates are used because the values are associated with exposure-response functions derived for the United States. Values are given in 1986 U.S. dollars which are converted to 1986 Canadian dollars using an average exchange rate for that year. Appendix A explains the derivation of these values.

The reader should recall that the object of this assignment was to examine the public benefits of alternative emission regulations. We have tried, where possible, to value those benefits in dollar terms. However, the fact that a benefit cannot be valued does not mean that it has no value. It may have great value to society and should be considered just as prominently by decision makers as those benefits to which values have been assigned.

Equally, it is not possible to value in dollar terms the benefits of regulating chemicals whose effects are unknown. However, regulation may still have value. This may just be the value that people will put upon knowing that they or their environment are being exposed to less of the unknown.

EXHIBIT 3.5: VALUES USED FOR CALCULATING ECONOMIC MAGNITUDE OF REDUCED DAMAGES

Benefit Category		Value 1986 U.S. $	Value 1986 C $
Reduced Risk of Death			
	central	5,000,000	6,950,000
	lower	1,000,000	2,200,000
Emergency Room Visits			
	central	175	250
Restricted Activity Days			
	upper	52	70
	central	44	60
	lower	12	15
Hospital Days for Respiratory Conditions		1,050	1,450
Hospital Admissions for Respiratory Disease		6,500	8,580
Materials Damage		*	*
Visibility		*	*

Notes: * represents damages that are not quantified in damage functions on a per event basis.

Conversion rate: 1986 U.S. to 1986 Canadian dollars = 1.39.

Source: Appendix A, Exhibit A.8

4.0 RESULTS

This chapter presents the results of our analysis of the effects of reducing emissions of each of the 96 contaminants.

4.1 Contaminants For Which No Emissions Were Estimated

There are some 42 contaminants for which no emissions were estimated. These are listed in Exhibit 4.1. The absence of estimated emissions occurs for several reasons:

- Ozone is not emitted. It is formed in the atmosphere as a result of chemical reactions between VOC's and nitrogen oxides. Hence the absence of ozone emissions is expected.

- Some contaminant definitions, such as asbestos fibres of length greater than five micrometers and inhalable particulate, are based on distinctions that can not be sustained by the empirical data. Hence it was necessary to analyse these contaminants as part of a larger category, total asbestos and total suspended particulate for the two examples given above.

- Most of the contaminants for which no emissions are estimated are VOC's. In these cases the absence of emissions estimates means that the contaminant did not appear in the VOC speciation. This could be an accurate reflection of the emissions of the specified industries. Or the contaminant might appear only in a minor SCC which was excluded in the speciation process. If these contaminants are emitted by Regulation 308 Sources, their emissions will likely be reduced by the measures implemented to control other VOC emissions.

EXHIBIT 4.1: CONTAMINANTS FOR WHICH NO EMISSIONS WERE ESTIMATED

Ammonia
Arsine
Asbestos (Fibers of length greater than 5 micrometers)
(Combined with Total Asbestos)
Benzo(a)pyrene
Berrylium
Calcium Cyanide (As total salt)
Captan
Chlordane
Chromium
Coal Tar Pitch Volatiles (Soluble Fraction)
Chromium (Di,Tri and Hexavalent Forms)
(Combined with Chromium)
Ethylene Glycol Butyl Ether Acetate (Butyl Cellosolve Acetate)
Hexachlorocyclopentadiene
Hydrogen Cyanide
Hydrogen Sulphide
Inhalable Particulates (Less than 10 micrograms)
(Included with Suspended Particulate)
Mercaptans
Mercury (Alkyl)
Methane Diphenyl Diisocyanate
4,4-Methylene-bis-2-chlorol-aniline
Nickel Carbonyl
Nitrous Oxide
Ozone
Pentachlorobenzenes
Pentachlorophenol
Phosgene
Phosphine
Polycyclic Aromatic Hydrocarbons (PAH's)
Polycyclic Organic Matter
Potassium Cyanide (As total salt)
Potassium Hydroxide
Propylene Glycol Methyl Ether
Propylene Glycol Monomethyl Ether Acetate
Sodium Cyanide (As total salt)
Sodium Hydroxide
Sulphuric Acid
Tetrachlorobenzenes
Tetrachlorophenols
Thiourea
Total Reduced Sulphur (TRS) as equivalent H_2S
1,2,4-Trichlorobenzene
Tricholorophenols

It is possible that some of these contaminants are emitted by establishments in Ontario. However, they were not identified by Senes and did not appear in the PM and VOC speciations. In the absence of emissions data it is not possible to estimate benefits associated with reduced emissions of these contaminants.

4.2 Contaminants For Which Emissions Were Estimated

The 54 contaminants for which we evaluated the public benefits due to reduced emissions from Regulation 308 Sources are listed in Exhibit 4.2. The exhibit identifies the human health and other effects expected from each contaminant. A more detailed explanation of the key follows.

C. Identifies contaminants for which cancer effects are expected and a unit risk factor is available to quantify these impacts. In these cases, the change in concentration of the contaminant is related to the exposed population to calculate the change in cancer mortality.

D. Identifies contaminants for which cancer effects are expected, but a unit risk function is not available. This includes chlorinated dibenzo dioxins (CDD's), a class of chemicals some of which, such as 2,7,3,8 Tetrachloro-dibenzo-p-dioxin, may be highly carcinogenic. The impact of reduced emissions on cancer mortality can not be estimated for these contaminants.

H. Identifies contaminants for which other (i.e., systemic) human health effects are expected and a standard(s) has been established to protect against them. This is the case for most of the chemicals for which we had emissions data. In two cases (sulphur dioxide, and particulate matter) exposure-response functions were also available, and it was possible to quantify specific health benefits.

EXHIBIT 4.2: EXPECTED IMPACTS BY CONTAMINANT WHERE EMISSIONS DATA WERE AVAILABLE

Acrylonitrile	C	H		
Arsenic	C	H		
Asbestos (Total)	C	H		
Benzene	C	H		
1,3 Butadiene	C			
2-Butanone (Methyl Ethyl Ketone)		S		
Butyl Acrylate		H		
Cadmium	C	H	P	
Carbon Tetrachloride	C	H		
Chlorinated Dibenzo Dioxins (CDD's)	D	H		
Chlorinated Dibenzo Furans (CDF's)	D	H		
Chlorine		H	P	
Chlorine Dioxide		H		
Chloroform	C	H		
Chromium	C	H		
Epichlorohydrin	C	H		
Ethyl Benzene		H		
Ethylene		S	P	
Ethylene Dibromide	D	H		
Ethylene Dichloride	C	H		
Ethylene Glycol Butyl Ether (Butyl Cellosolve)		S		
Ethylene Glycol Ethyl Ether (Cellosolve)		S		
Ethylene Gylcol Ethyl Ether Acetate (Cellosolve Acetate)		S		
Ethylene Oxide	D	H		
Fluorides (Total)	H	P		
Formaldehyde	C	H		
Hydrogen Chloride		H	P	
Lead		H		
Manganese Compounds		H		
Mercury		H		
Methyl Isobutyl Ketone		H	O	
Methylene Chloride	C	H		
Naphthalene		H	O	
Nickel	C	H	P	
Nitrogen Oxides		H	V	M
Perchloroethylene		H		
Phenol		H		
Polychlorinated Biphenyls (PCB's)	C	H		
Propionaldehyde		S	O	
Propionic Acid		H		
Propylene Oxide	C	H		
Selenium	D	H	P	
Silica		H		
Styrene	C	H	O	

EXHIBIT 4.2: EXPECTED IMPACTS BY CONTAMINANT WHERE EMISSIONS DATA WERE AVAILABLE (Continued)

Sulphur Dioxide		H	P	
Suspended Particulate Matter		H	V	M
Tin		H		
Toluene		H		
Toluene Diisocyanate	C	H		
1,1,1 - Trichloroethane (Methyl Chloroform)	C	H		
Trichlorobenzenes		H		
Trichloroethylene	C	H	O	
Vinyl Chloride	C	H		
Xylenes		H		

Key:

C = Cancer effects expected and Unit Risk Function available.
D = Probable or suspected carcinogen, but no Unit Risk Function available.
H = Systemic human health effects expected and air quality standard established.
S = Air quality standard established, systemic human health effects unknown.
P = Phytotoxic.
V = Visibility effects.
M = Materials damage effects.
O = Odour effects.

S. Identifies contaminants for which standards have been established, but whose systemic health effects are unknown.

P. Identifies contaminants that are phytotoxic, contaminants expected to damage plants, particularly crops and forests. In these cases we calculated the areas of cropland or commercial forest cover exposed to the contaminant under each scenario. Some regulatory standards (for example, for ethylene and fluorides) have been set specifically for plant or forage protection.

O. Identifies contaminants for which odour effects are expected. We did not conduct a separate analysis for odour effects. The odour effects can be inferred from the population exposed to the contaminant under different scenarios.

V. Identifies contaminants which are expected to affect visibility.

M. Identifies contaminants which are expected to result in materials damage. Nitrogen dioxide and particulate matter are the two contaminants expected to have visibility and materials damage effects. Exposure-response functions are available for these effects and the benefits (valued in dollar terms) of different emission levels are calculated for them.

4.3 Acrylonitrile

Acrylonitrile is a carcinogen and is very toxic. Our analysis of the reduction in acrylonitrile emissions that would be achieved under the proposed revisions to Regulation 308 indicates that

there would be a negligible impact on cancer deaths under all scenarios.

No monitoring data are available for acrylonitrile, hence we were able to calculate only the effects due to changes in concentration attributable to Regulation 308 Source emissions.

The ambient air quality standard included in the proposed revisions to Regulation 308 is 100 micrograms per cubic metre averaged over 24 hours. We converted this to an annual average of 20 micrograms per cubic metre.

The areas affected by acrylonitrile emissions from Regulation 308 Sources are shown in Exhibit I.1 (Appendix I). Most of the areas are in southern Ontario; these areas together with their population densities are shown in Exhibit 4.3. The proposed standard, on an annual equivalent basis, is not exceeded anywhere in the province.

A profile of acrylonitrile concentrations under different scenarios is shown in Exhibit 4.4. The profile gives the concentrations along the diagonal line shown in Exhibit 4.3. The line runs from Windsor through London, Kitchener-Waterloo and Metropolitan Toronto, then just south of Ottawa to the Quebec border as shown in Exhibit I.2.

The highest concentrations from Regulation 308 Sources are in the Toronto area. At present these concentrations are generally less than 0.02 micrograms per cubic metre; about one percent of the annual equivalent of the proposed standard. The proposed revisions to Regulation 308 would reduce the peak concentrations by approximately 75 percent.

EXHIBIT 4.3: AREAS AFFECTED BY DISPERSION OF ACRYLONITRILE EMISSIONS FROM REGULATION 308 SOURCES

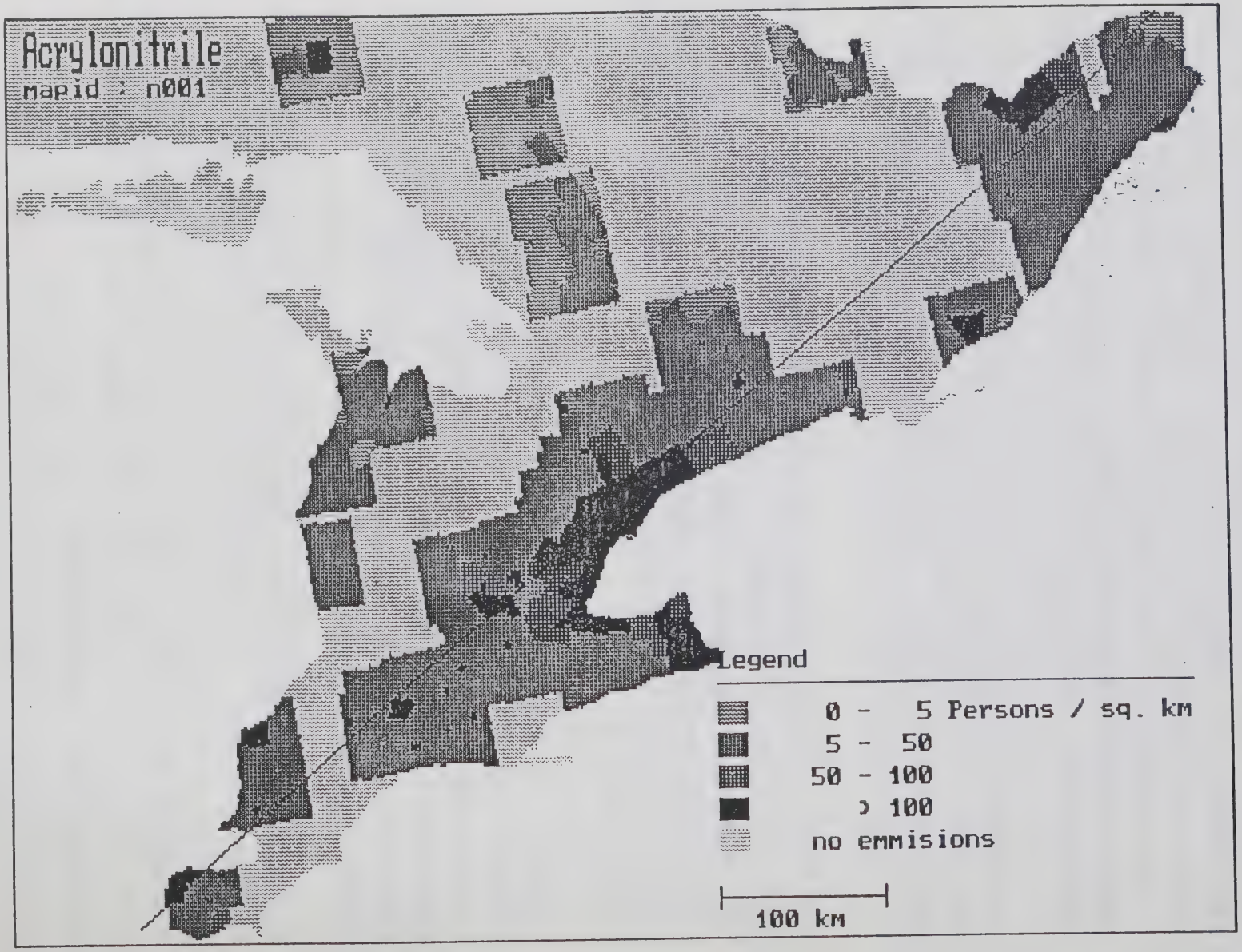
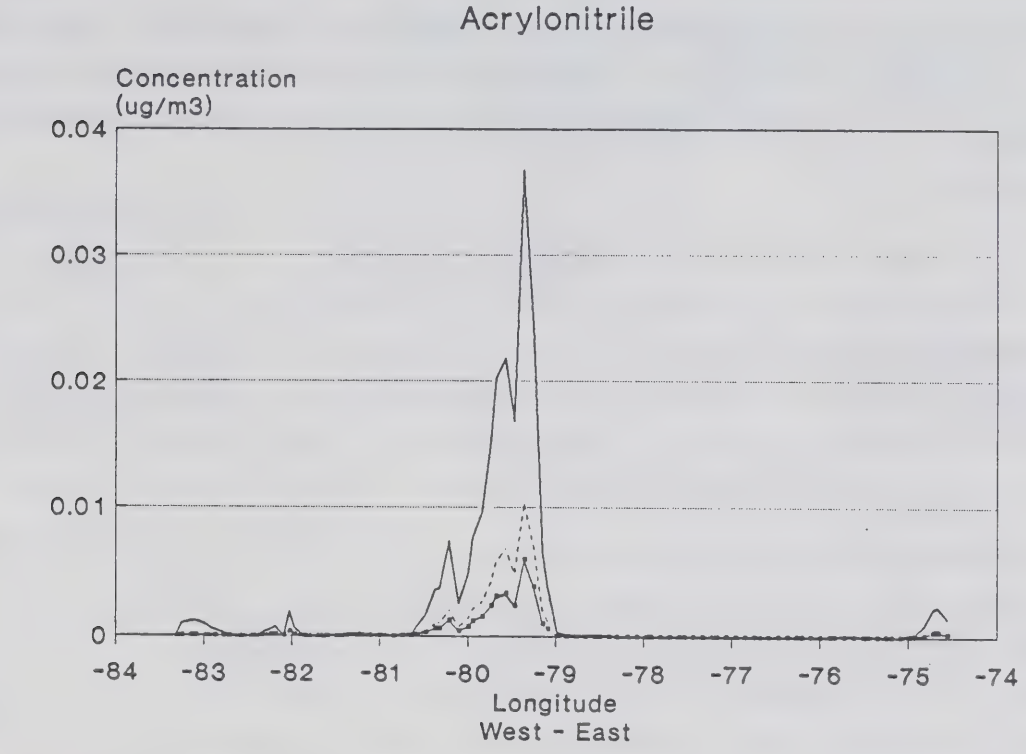


EXHIBIT 4.4: PROFILE OF THE CONCENTRATION OF ACRYLONITRILE ACROSS SOUTHERN ONTARIO DUE TO EMISSIONS BY REGULATION 308 SOURCES



4.4 Arsenic

Arsenic is a carcinogen. It also poses a health risk through irritation of the skin and mucous membranes.

Our analysis indicates that the emission controls required under the proposed revisions to Regulation 308 would reduce cancer mortality by six to eight deaths per year. These result are as follows:

	Reduced Cancer Deaths/Year	Range of Economic Benefits/Year (1986 C$)
Scenarios "A" & "D"	7	$15 - 49 million
Scenario "B"	8	$17 - 56 million
Scenario "C"	6	$13 - 42 million
Scenario "E"	7	$15 - 49 million

No monitoring data are available for arsenic, hence our analysis is limited to the estimated emissions from Regulation 308 Sources. The proposed revisions to Regulation 308 include an ambient air standard of 0.3 micrograms per cubic metre averaged over 24 hours. We converted this to an equivalent of 0.06 micrograms per cubic metre as an annual average.

Our analysis indicates that this standard is exceeded by the estimated current emissions from Regulation 308 Sources. The population exposed to above threshold concentrations of arsenic from Regulation 308 Sources by scenario is as follows:

	Area (km^2)	Population	Change from Current Area	Change from Current Population
Current	5,872	228,000	-	-
Scenarios "A" & "D"	352	34,000	-94%	-85%
Scenario "B"	352	34,000	-94%	-85%
Scenario "C"	832	67,000	-85%	-71%
Scenario "E"	352	34,000	-94%	-85%

The areas exposed to above annual equivalent threshold concentrations of arsenic from Regulation 308 Sources under each scenario are shown in Exhibit 4.5.

The dispersion of arsenic emissions from Regulation 308 Sources is shown in Exhibit I.3 (Appendix I). The profiles of arsenic concentration across southern Ontario due to emissions by Regulation 308 Sources are presented in Exhibit I.4.

4.5 Asbestos

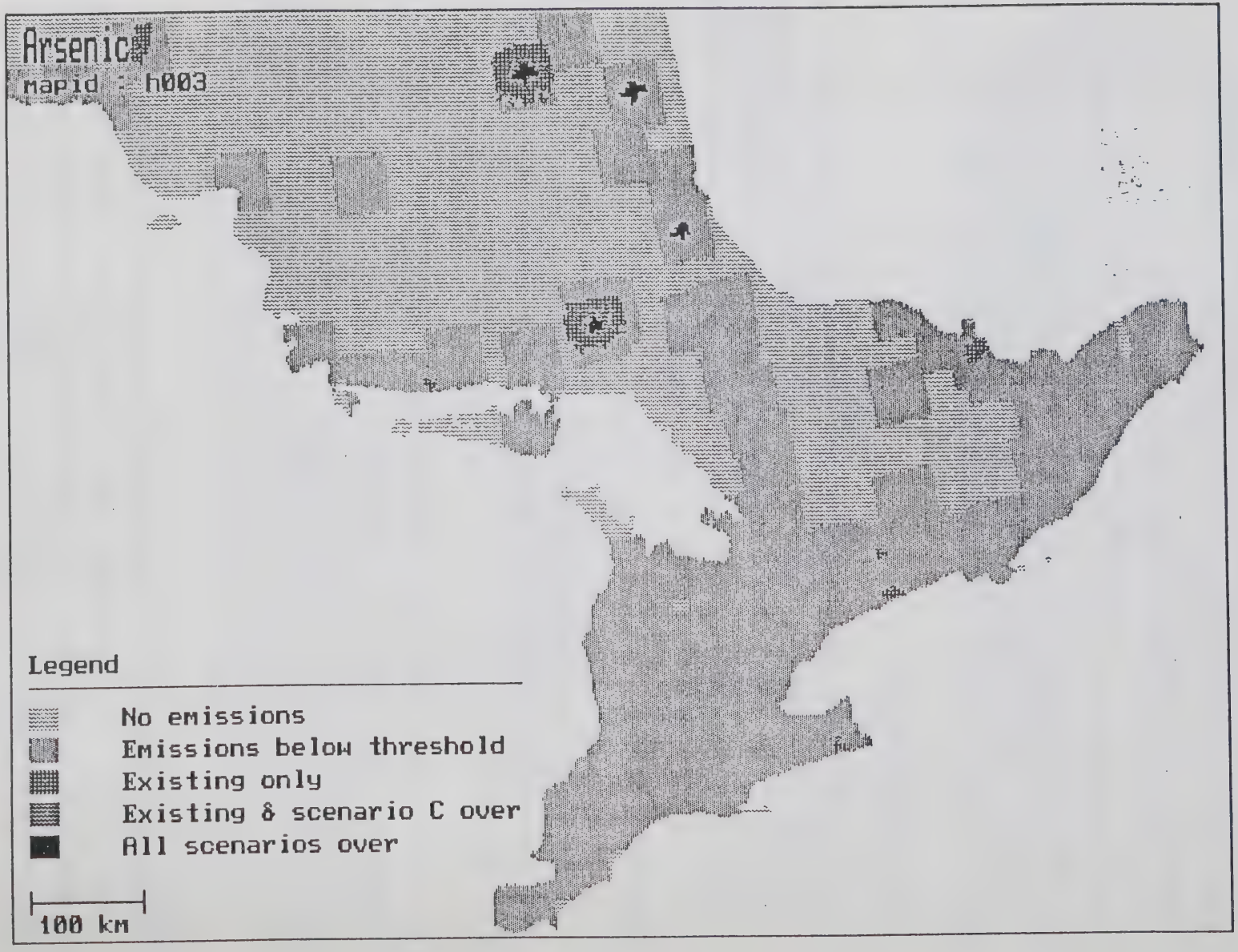
The proposed ambient concentration standards for Regulation 308 distinguish asbestos fibres of length greater than 5 micrometers and total asbestos. The emissions estimates and health impact data do not permit such a distinction in our analysis. We deal with total asbestos which is considered a carcinogen and a cause of asbestosis.

The reduction in annual cancer deaths due to implementation of the proposed revisions to Regulation 308 is negligible under all scenarios.

No monitoring data are available for asbestos. The ambient air standard included in the proposed revisions to Regulation 308 is 1.6 micrograms per cubic metre averaged over 24 hours. We converted this to 0.32 micrograms per cubic metre as an annual average. This proposed standard is not exceeded by the current emissions of asbestos from Regulation 308 Sources.

The areas exposed to asbestos emissions from Regulation 308 Sources and the population densities in those areas are shown in Exhibit I.5 (Appendix I). The concentration profile by scenario across southern Ontario is shown in Exhibit I.6.

EXHIBIT 4.5: AREAS OF ARSENIC CONCENTRATIONS THAT EXCEED THRESHOLD LEVELS AS A RESULT OF REGULATION 308 SOURCE EMISSIONS ALONE



4.6 Benzene

Benzene is considered a carcinogen. Acute exposure results in irregular heart rate, dizziness, headache, nausea, and loss of consciousness.

Lower emissions resulting from implementation of the proposed revisions to Regulation 308 would have an insignificant effect on cancer mortality.

The proposed revisions to Regulation 308 include an air quality standard of 3,300 micrograms per cubic metre averaged over 24 hours, which we converted to 660 micrograms per cubic metre as an annual average. We found that the concentrations due to emissions of benzene from Regulation 308 Sources do not exceed this standard.

The areas affected by benzene emissions from Regulation 308 Sources are shown in Exhibit I.7 (Appendix I). The concentration profile for benzene from Regulation 308 Sources across southern Ontario is shown in Exhibit I.8.

4.7 1,3 Butadiene

The U.S. EPA considers butadiene a probable human carcinogen. It irritates skin and mucous membranes. High concentrations depress the central nervous system and can result in death.

Reduced emissions resulting from implementation of the proposed revisions to Regulation 308 do not yield a significant impact on cancer mortality.

No ambient air standard is included in the proposed revisions to Regulation 308 for 1,3 butadiene. For our analysis we used the North Carolina standard of 110 micrograms per cubic metre

averaged over 24 hours. We converted this to an annual average of 22 micrograms per cubic metre. We found that concentrations due to emissions of 1,3 butadiene from Regulation 308 Sources do not exceed this standard.

The areas over which emissions of 1,3 butadiene by Regulation 308 Sources are dispersed are shown in Exhibit I.9. (Appendix I). The profile of concentrations due to Regulation 308 Source emissions across southern Ontario is shown in Exhibit I.10.

4.8 2-Butanone (Methyl Ethyl Ketone)

2-Butanone is not classified as a human carcinogen. The non-cancer health effects are not well-known.

The ambient air quality standard in the proposed revisions to Regulation 308 is 3,100 micrograms per cubic metre averaged over 1 hour, which we converted to 258 micrograms per cubic metre averaged over a year. This standard is based on the odour threshold. The standard is not exceeded by concentrations due to emissions from Regulation 308 Sources.

The methodology used in this study is not well suited to the analysis of odour impacts. Odour is a problem when concentrations exceed a detectable threshold. The frequency and duration of above threshold concentration occurrences are the critical variables. The assumption of a constant emission rate and the calculation of annual average concentrations serve to smooth out the critical occurrences. To adequately address odour reduction benefits requires some knowledge of the variability of emissions so that the effects of these fluctuations on concentrations can be analysed. The finding that concentrations do not exceed the proposed standard means that there is no area where odour is a continuous problem. Odour could still be a periodic problem.

The areas exposed to 2-butanone emissions from Regulation 308 Sources are displayed in Exhibit I.11 (Appendix I). The profile of concentrations due to Regulation 308 Source emissions under each scenario is shown in Exhibit I.12.

4.9 Butyl Acrylate

Butyl acrylate is not classified as a human carcinogen, but inhalation leads to irritation of the respiratory tract. Monitoring data are not available.

The ambient air quality standard included in the proposed revisions to Regulation 308 is 35 micrograms per cubic metre averaged over 24 hours. We expressed this as 7 micrograms per cubic metre as an annual average. Our estimates of the concentrations resulting from butyl acrylate emissions by Regulation 308 Sources indicate that this threshold is not exceeded at present.

The areas exposed to butyl acrylate emissions from Regulation 308 Sources are displayed in Exhibit I.13 (Appendix I). The profile of concentrations due to Regulation 308 Source emissions under each scenario is presented in Exhibit I.14.

4.10 Cadmium

Cadmium is classified as a probable human carcinogen. Inhalation exposure can cause lung problems. Cadmium is also phytotoxic to crops and trees.

Our estimates of cancer death reductions resulting from lower cadmium emissions due to implementation of proposed revisions to Regulation 308 use the Massachusetts unit risk factor. The

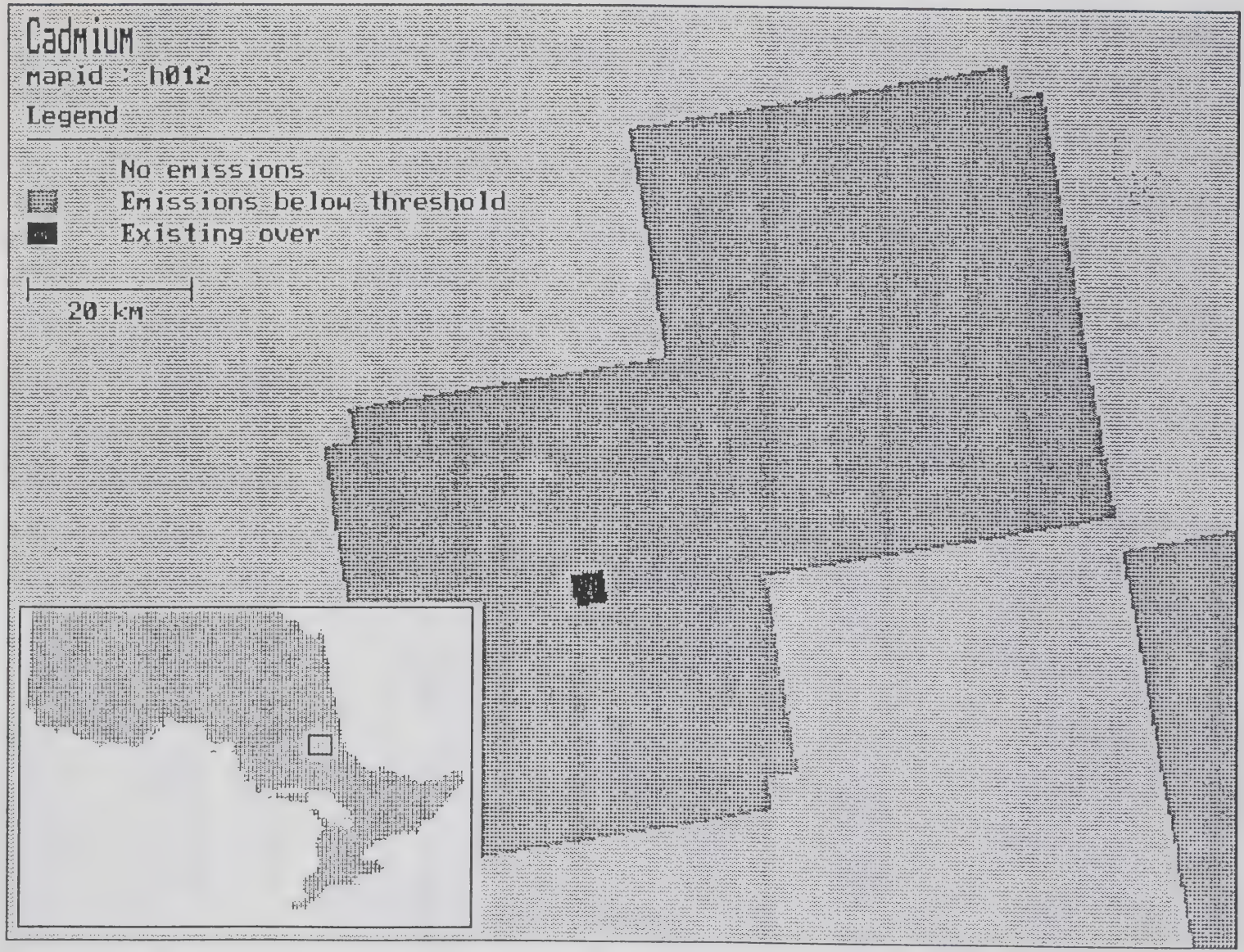
results indicate a negligible reduction in cancer deaths under each scenario.

The proposed ambient air standard for cadmium in the revisions to Regulation 308 is 2 micrograms per cubic metre averaged over 24 hours. We converted this to an equivalent of 0.4 micrograms per cubic metre as an annual average. The concentrations of cadmium due to emissions from Regulation 308 Sources do not exceed this proposed standard.

Monitoring data are available for cadmium and are used to estimate ambient concentrations from non-Regulation 308 sources. The maximum contribution of non-Regulation 308 sources in the areas affected by Regulation 308 emissions is estimated at 0.02 micrograms per cubic metre as an annual average. When this maximum value is added to the estimated concentrations attributable to Regulation 308 Source emissions, the threshold level is exceeded in a small area. The population exposed to above threshold concentrations at present in less than 500 people. As shown in Exhibit 4.6, this is reduced to nil by the proposed revisions to Regulation 308 regardless of the implementation scenario. Hence, the proposed revisions to Regulation 308 yield only marginal human health benefits in relation to cadmium.

The areas exposed to cadmium emissions are presented in Exhibit I.15. (Appendix I). The agricultural area exposed to cadmium emissions from Regulation 308 Sources is 26,821 square kilometers. This is 78 percent of Ontario's cropland. However, no areas are exposed to above threshold concentrations of cadmium. The profile of concentrations due to Regulation 308 Source emissions by scenario is shown in Exhibit I.16.

EXHIBIT 4.6: AREAS OF CADMIUM CONCENTRATIONS THAT EXCEED THRESHOLD LEVELS AS A RESULT OF EMISSIONS FROM ALL SOURCES



4.11 Carbon Tetrachloride

The U.S. Environmental Protection Agency considers carbon tetrachloride to be a probable human carcinogen. Non-cancer effects include depression of the central nervous system, loss of consciousness, dizziness, vertigo, headaches, depression, mental confusion and incoordination.

Our analysis of the change in cancer mortality resulting from implementation of the proposed revisions to Regulation 308 indicate a negligible saving of life.

The proposed revisions to Regulation 308 include an ambient air standard of 600 micrograms per cubic metre averaged over 24 hours, which we converted to an annual average concentration of 120 micrograms per cubic metre. We found that concentrations due to emissions from Regulation 308 Sources do not exceed this proposed standard.

The areas exposed to emissions of carbon tetrachloride from Regulation 308 Sources are displayed in Exhibit I.17 (Appendix I). The profiles of carbon tetrachloride concentrations due to emissions by Regulation 308 Sources by scenario are shown in Exhibit I.18.

4.12 Chlorinated Dibenzo Dioxins (CDD's)

We have selected 2,3,7,8-tetrachloro-dibenzo-p-dioxin, which is probably more carcinogenic than most CDD's, to get a sense of the health effects of these chemicals. CDD's are regarded as carcinogenic although no unit risk factors are available. The chronic health effects of exposure to CDD's are not known.

The proposed revisions to Regulation 308 include an ambient air standard of 30 picograms (0.00003 micrograms) per cubic metre as

an annual average. The concentrations due to emissions from Regulation 308 sources do not exceed this proposed standard.

The areas exposed to emissions of CDD's from Regulation 308 Sources are shown in Exhibit I.19 (Appendix I). The profile of CDD concentration due to Regulation 308 Source emissions under each scenario are presented in Exhibit I.20.

4.13 Chlorinated Dibenzo Furans (CDF's)

Like CDD's, CDF's are considered carcinogenic although unit risk factors are not available. The chronic health effects of exposure to CDF's are not known.

The proposed revisions to Regulation 308 include an ambient air standard of 1500 picograms (0.0015 micrograms) per cubic metre as an annual average. The concentrations due to emissions from Regulation 308 Sources do not exceed this proposed standard.

The areas exposed to emissions of CDF's from Regulation 308 Sources are shown in Exhibit I.21 (Appendix I). The profiles of CDF concentration due to Regulation 308 Source emissions under each scenario are presented in Exhibit I.22.

4.14 Chlorine

Chlorine is not a carcinogen. Exposures may result in scratchiness of the throat, pulmonary edema and congestion depending upon the concentration. Chlorine is a known phytotoxicant.

The ambient air standard included in the proposed revisions to Regulation 308 is 150 micrograms per cubic metre averaged over 24 hours. We translated this proposed standard to 30 micrograms per cubic metre as an annual average. Concentrations due to

emissions from Regulation 308 Sources do not exceed this proposed standard.

The areas effected by exposures to chlorine from Regulation 308 Sources are displayed in Exhibit I.23 (Appendix I). Some 6,171 square kilometers of agricultural land are exposed to chlorine emissions from Regulation 308 Sources. But there are no areas where these concentrations exceed the proposed threshold. The profiles of chlorine concentration due to emissions by Regulation 308 Sources by scenario are shown in Exhibit I.24.

4.15 Chlorine Dioxide

Chlorine dioxide is not a carcinogen. It has been linked to respiratory irritation and prolonged exposure may cause bronchitis and pronounced emphysema.

The ambient air standard included in the proposed revisions to Regulation 308 is 30 micrograms per cubic metre averaged over 24 hours, which we converted to 6 micrograms per cubic metre as an annual average. Concentrations of chlorine dioxide due to emissions from Regulation 308 Sources do not exceed this proposed standard.

The areas exposed to chlorine dioxide emissions by Regulation 308 Sources are displayed in Exhibit I.25 (Appendix I). The profiles of chlorine dioxide concentration due to emissions from Regulation 308 Sources by scenario are shown in Exhibit I.26.

4.16 Chloroform

Chloroform is considered a carcinogen and can also damage the liver, kidneys and central nervous system.

The Massachusetts unit risk factor was used in the cancer analysis. Our calculations indicate that the proposed revisions to Regulation 308 will reduce cancer mortality due to chloroform by a negligible amount under all scenarios.

The ambient air standard included in the proposed revisions to Regulation 308 is 500 micrograms per cubic metre averaged over 24 hours. We expressed this as 100 micrograms per cubic metre as an annual average. Concentrations due to emissions from Regulation 308 Sources alone do not exceed this proposed standard.

The areas affected by exposures to chlorine from Regulation 308 Sources are displayed in Exhibit I.27 (Appendix I). The profiles of chloroform concentration due to emissions from Regulation 308 Sources by scenario are shown in Exhibit I.28.

4.17 Chromium

The different forms of chromium -- chromium, dichromium; trichromium and hexavalent chromium -- could not be distinguished in the emissions estimates. We treated all chromium emissions as hexavalent chromium, the most toxic form. It is a carcinogen and causes irritation and damage to the respiratory tract, the liver and the kidneys.

The estimated reduction in cancer deaths due to the proposed revisions to Regulation 308 are shown below:

	Reduced Cancer Deaths/Year	Range of Economic Benefits/Year (1986 C$)
Scenarios "A" & "D"	8	$17 - 56 million
Scenario "B"	8	$17 - 56 million
Scenario "C"	4	$ 9 - 28 million
Scenario "E"	8	$17 - 56 million

The estimated reduction in cancer mortality for chromium is probably overstated. It was necessary to apply the cancer unit risk factor for the most virulent form -- hexavalent chromium -- to all chromium emissions thus raising the estimated reduction in cancer mortality.

The ambient air standard for all forms of chromium included in the proposed revisions to Regulation 308 is 1.5 micrograms per cubic metre averaged over 24 hours. We converted this to an annual average 0.3 micrograms per cubic metre. Concentrations due to emissions from Regulation 308 Sources alone exceed this proposed standard at present. The population exposed to above threshold concentrations of chromium from Regulation 308 Sources alone is 34 thousand under existing regulations. This remains unchanged under Scenario C. But under all other scenarios for implementation of the proposed revisions to Regulation 308 no one would be exposed to above threshold concentrations of chromium from Regulation 308 Sources.

The monitoring data suggest that ambient concentrations of chromium due to non-Regulation Sources in the areas affected by Regulation 308 emissions are less than 0.04 micrograms per cubic metre as an annual average. When this maximum value is used as the concentration due to non-Regulation 308 sources and added to the emissions from Regulation 308 Sources, the population exposed to above threshold concentrations of chromium is as follows:

	Area (km^2)	Population	Change from Current Area	Change from Current Population
Current	64	75,000	-	-
Scenarios "A" & "D"	16	26,000	-75%	-65%
Scenario "B"	16	26,000	-75%	-65%
Scenario "C"	32	34,000	-50%	-55%
Scenario "E"	16	26,000	-75%	-65%

This result must interpreted with caution. Exhibit 4.7 shows that these threshold exceedances occur in a small number of grid cells in Hamilton area. That in turn could result from the concentration of establishments at selected grid points.

The areas exposed to chromium emissions from Regulation 308 Sources under each scenario are shown in Exhibit I.29 (Appendix I). The profiles of chromium concentration due to emissions from Regulation 308 Sources by scenario are shown in Exhibit I.30.

4.18 Epichlorohydrin

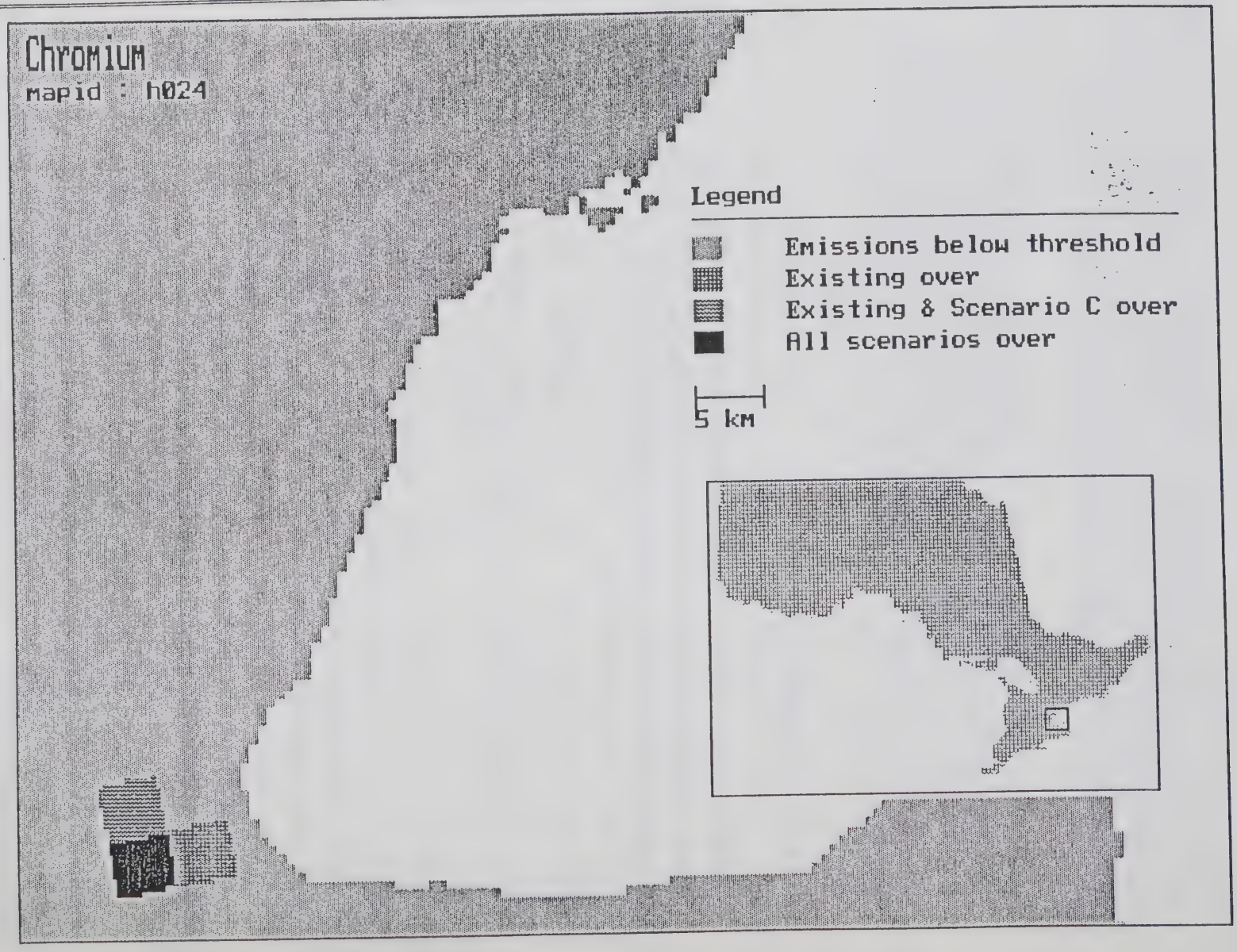
Epichlorohydrin is considered a probable carcinogen. It can also cause burning of eyes and nasal passages, severe chemical burns on skin contact and possibly skin dermatitis.

Our analysis indicates that the reduction is annual cancer deaths due to implementation of the proposed revisions to Regulation 308 is negligible under all scenarios.

No ambient air standard for epichlorohydrin is included in the proposed revisions to Regulation 308. For our analysis we used the Massachusetts standard of 2.7 micrograms per cubic metre averaged over 24 hours. We then converted this to 0.54 micrograms per cubic metre as an annual average. Concentrations due to emissions from Regulation 308 Sources alone do not exceed this proposed standard.

The areas exposed to epichlorohydrin emissions from Regulation 308 Sources are displayed in Exhibit I.31 (Appendix I). The profiles of epichlorohydrin concentration due to emissions from Regulation 308 Sources by scenario are presented in Exhibit I.32.

EXHIBIT 4.7: AREAS OF CHROMIUM CONCENTRATIONS THAT EXCEED THRESHOLD LEVELS AS A RESULT OF EMISSIONS FROM ALL SOURCES



4.19 Ethyl Benzene

Ethyl benzene is an irritant to the skin and mucous membranes. It is not considered carcinogenic.

The ambient air standard included in the proposed revisions to Regulation 308 is 4,000 micrograms per cubic metre averaged over one hour. We converted this to an equivalent standard of 333 micrograms per cubic metre as an annual average. Concentrations due to emissions from Regulation 308 Sources alone do not exceed this proposed standard.

The areas exposed to ethyl benzene emissions from Regulation 308 Sources are displayed in Exhibit I.33 (Appendix I). The profiles of ethyl benzene concentrations due to emissions from Regulation 308 Sources by scenario are presented in Exhibit I.34.

4.20 Ethylene

Ethylene is not considered carcinogenic and no other health effects are known. However, ethylene is phytotoxic and the proposed Regulation 308 standard of 40 micrograms per cubic metre over 24 hours is established on this basis. We translated this standard into an annual average equivalent of 8 micrograms per cubic metre. Concentrations due to emissions from Regulation 308 Sources alone do not exceed this proposed standard.

The areas exposed to ethylene emissions from Regulation 308 Sources are shown in Exhibit I.35 (Appendix I). The total amount of agricultural land in these areas is 25,353 square kilometers. No agricultural land is exposed to above threshold concentrations of ethylene due to Regulation 308 Source emissions. The profiles of ethylene concentration due to

emissions from Regulation 308 Sources by scenario are presented in Exhibit I.36.

4.21 Ethylene Dibromide

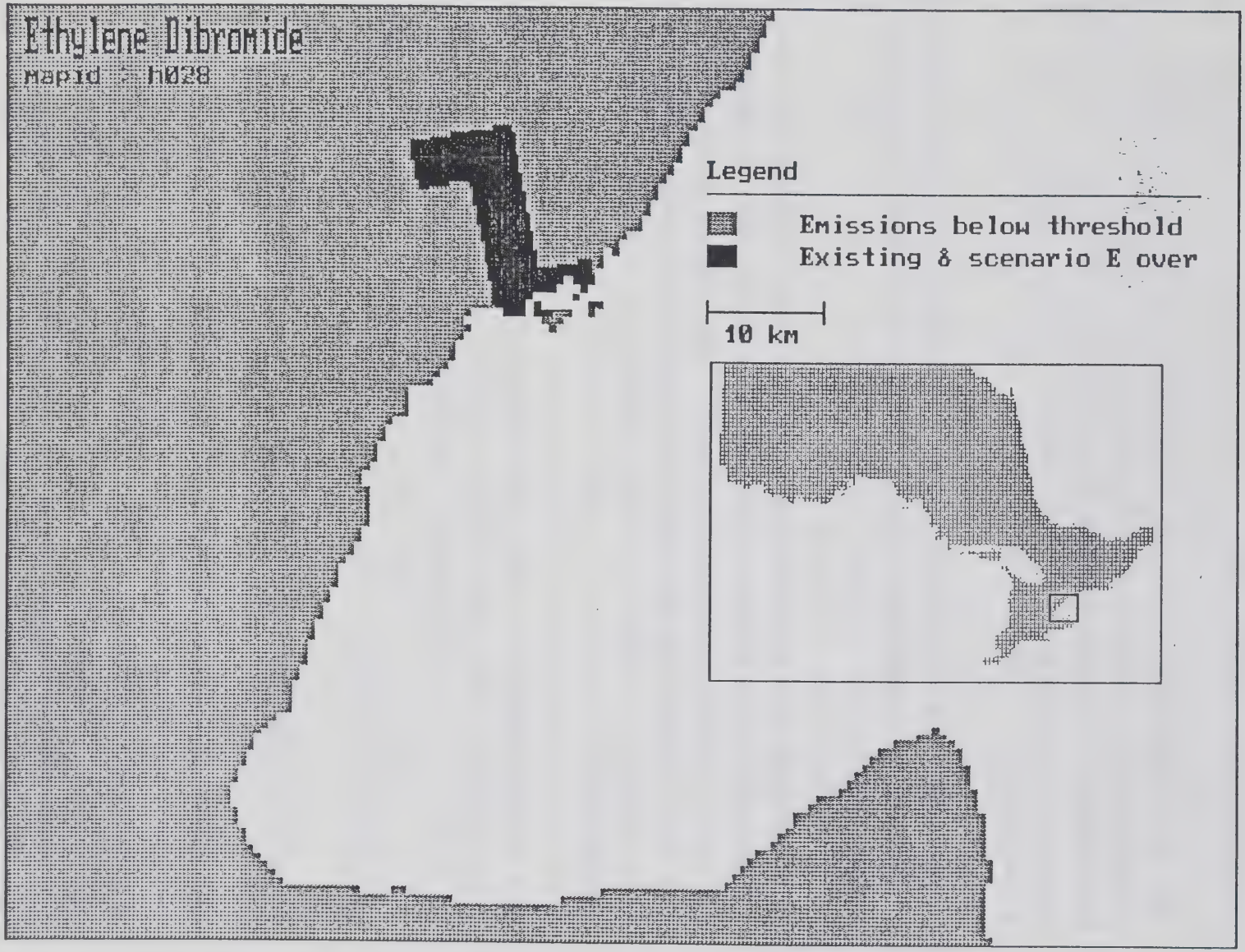
There are suggestions that ethylene dibromide should be treated as a potential carcinogen. Ethylene dibromide causes irritation and injury to the skin and eyes. Long term exposure may cause injury to the lungs, liver and kidney. No unit risk factor is available to enable us to estimate a cancer related benefit due to reduced emissions.

No ambient air standard is included in the proposed revisions to Regulation 308 for ethylene dibromide. Our analysis uses the North Carolina standard of 0.045 micrograms per cubic metre averaged over one year. Concentrations due to emissions from Regulation 308 Sources alone exceed this proposed standard at present and under Scenario E.

The population exposed to above threshold concentrations of ethylene dibromide from Regulation 308 Sources at present and under Scenario E is 345,000 in an area of 96 km^2 in Metropolitan Toronto. The areas exposed to above threshold concentrations are shown in Exhibit 4.8. We understand that the result for Scenario E may stem from an error in the input data provided to us by Senes.

The areas exposed to concentrations of ethylene dibromide emissions by Regulation 308 Sources are displayed in Exhibit I.37 (Appendix I). The profiles of ethylene dibromide concentration due to emissions by Regulation 308 Sources by scenario are presented in Exhibit I.38.

EXHIBIT 4.8: AREAS OF ETHYLENE DIBROMIDE CONCENTRATIONS THAT EXCEED THRESHOLD LEVELS AS A RESULT OF EMISSIONS FROM REGULATION 308 SOURCES ALONE



4.22 Ethylene Dichloride

The EPA considers ethylene dichloride a probable human carcinogen. Inhalation can also cause irritation of mucous membranes, central nervous system depression, and congestion and degenerative effects on the liver, kidney, spleen, lungs and adrenals.

Using the IRIS unit risk factor, the effects of the proposed revisions to Regulation 308 in terms of reduced cancer deaths are negligible.

The ambient air standard included in the proposed revisions to Regulation 308 is 400 micrograms per cubic metre averaged over 24 hours. We converted this to an equivalent of 80 micrograms per cubic metre as an annual average. Concentrations due to emissions from Regulation 308 Sources do not exceed this proposed standard.

The areas exposed to ethylene dichloride emissions by Regulation 308 Sources are displayed in Exhibit I.39 (Appendix I). The profiles of ethylene dichloride concentration due to emissions by Regulation 308 Sources by scenario are presented in Exhibit I.40.

4.23 Ethylene Glycol Butyl Ether (Butyl Cellosolve)

Although the health effects of ethylene glycol butyl ether (butyl cellosolve) are uncertain, the Ministry of the Environment has established an ambient air standard as part of the proposed revisions to Regulation 308. That proposed standard is 300 micrograms per cubic metre averaged over one hour, which we converted to 25 micrograms per cubic metre as an annual average. That standard is not exceeded by concentrations due to emissions from Regulation 308 Sources.

The areas affected by ethylene glycol butyl ether emissions from Regulation 308 Sources are shown in Exhibit I.41 (Appendix I). The profiles of butyl cellosolve concentration due to emission by Regulation 308 Sources by scenario are presented in Exhibit I.42.

4.24 Ethylene Glycol Ethyl Ether (Cellosolve)

The health effects of ethylene glycol ethyl ether (cellosolve) are uncertain, but the Ministry of the Environment has established an ambient air standard as part of the proposed revisions to Regulation 308. That proposed standard is 665 micrograms per cubic metre averaged over one hour, which we converted to 55.4 micrograms per cubic metre as an annual average. This proposed standard is not exceeded by concentrations due to Regulation 308 Sources alone.

The areas exposed to concentrations of ethylene glycol ethyl ether (cellosolve) from Regulation 308 Source emissions are identified in Exhibit I.43 (Appendix I). The profiles of cellosolve concentration due to emissions by Regulation 308 Sources by scenario are presented in Exhibit I.44.

4.25 Ethylene Glycol Ethyl Ether Acetate (Cellosolve Acetate)

Although the health effects of ethylene glycol ethyl ether acetate (cellosolve acetate) are uncertain, the Ministry of the Environment has established an ambient air standard as part of the proposed revisions to Regulation 308. That proposed standard is 180 micrograms per cubic metre averaged over one hour, which we expressed as 15 micrograms per cubic metre as an annual average. This proposed standard is not exceeded by concentrations due to Regulation 308 Source emissions.

The areas exposed to emissions of ethylene glycol ethyl ether acetate (cellosolve acetate) from Regulation 308 Sources are displayed in Exhibit I.45 (Appendix I). The profiles of cellosolve acetate concentration due to emissions by Regulation 308 Sources by scenario are presented in Exhibit I.46.

4.26 Ethylene Oxide

Ethylene oxide is a possible carcinogen, but a unit risk factor has not yet been established. A benefit in the form of lower cancer mortality due to reduced ethylene oxide emissions can not be estimated.

Acute exposures to ethylene oxide cause acute illness with nausea, vomiting and headache. The health benefits of lower ethylene oxide emissions are evaluated by examining the number of people exposed under each scenario.

The ambient air quality standard included in the proposed revisions to Regulation 308 is 5 micrograms per cubic metre averaged over 24 hours. We converted the standard to 1 microgram per cubic metre as an annual average. This threshold is not exceeded by concentrations due to Regulation 308 Source emissions.

The areas affected by Regulation 308 Source emissions of ethylene oxide are shown in Exhibit I.47 (Appendix I). The profiles of ethylene oxide concentration due to emissions by Regulation 308 Sources by scenario are presented in Exhibit I.48.

4.27 Fluorides

Fluorides are not considered carcinogenic. They can have adverse effects on human health, but the ambient air standard in the proposed revisions to Regulation 308 is set to protect animals

from adverse effects due to elevated fluoride levels in forage. The proposed ambient air quality standard is 1.72 micrograms per cubic metre averaged over 24 hours. We converted this to 0.344 micrograms per cubic metre as an annual average. This proposed standard is exceeded by current emissions from Regulation 308 Sources.

The above threshold value of fluorides occurs in one grid cell ($16km^2$) with a population of 225 people (see Exhibit 4.9). All of the implementation scenarios result in the elimination of above threshold concentrations of fluorides due to Regulation 308 Source emissions.

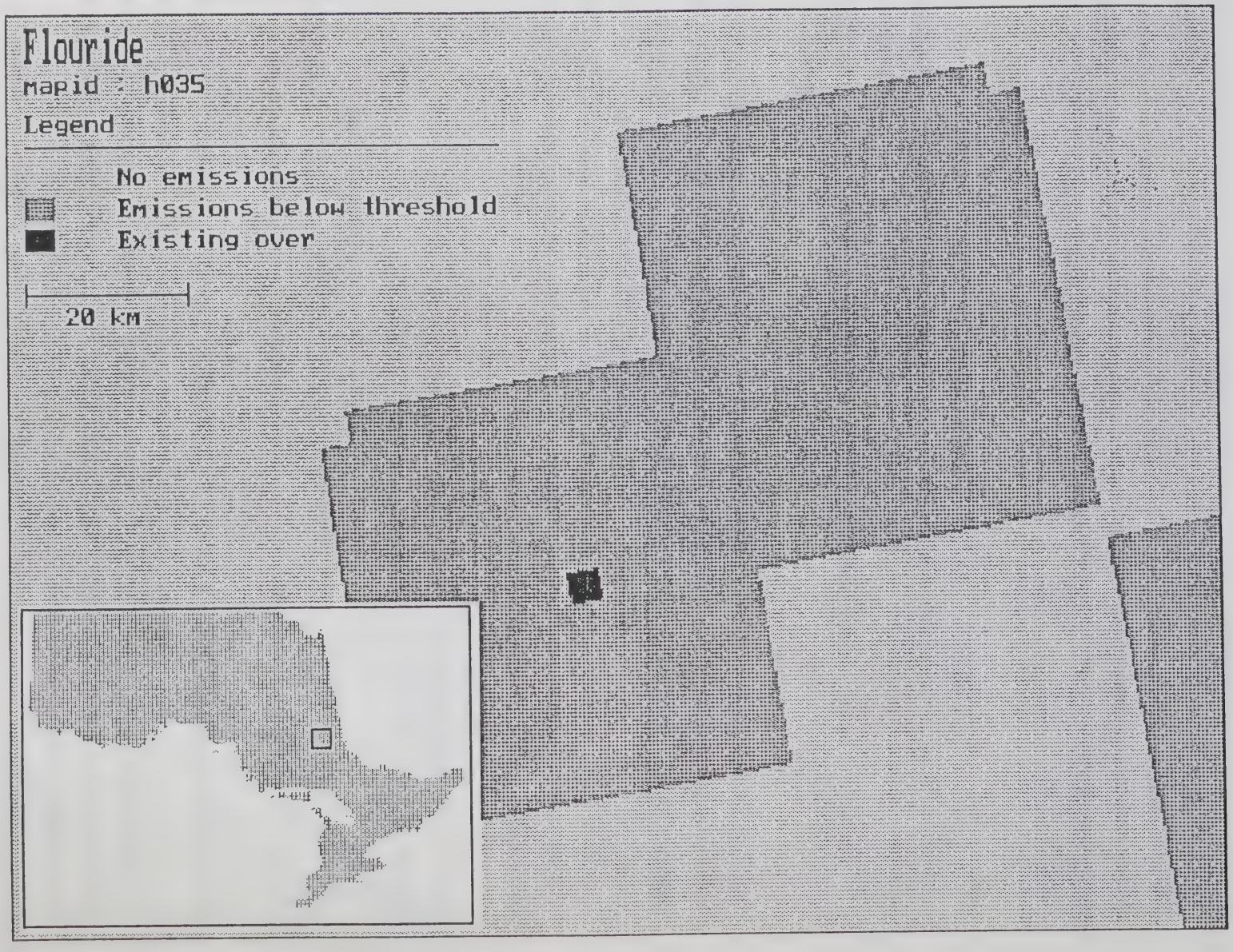
No agricultural land is exposed to above threshold concentrations of fluorides at present (the one grid cell is not an agricultural area) or under any implementation scenario. The total area of agricultural land exposed to fluorides emissions form Regulation 308 sources is 24,982 square kilometers (73 percent of Ontario's cropland). We repeat that the concentrations are below the proposed standard in all cases.

The areas affected by fluoride concentrations due to Regulation 308 Source emissions are shown in Exhibit I.49 (Appendix I). The profiles of fluoride concentration due to emissions by Regulation 308 Sources by scenario are presented in Exhibit I.50.

4.28 Formaldehyde

Formaldehyde is believed to cause nasal cancer. Its non-lethal effects on human health are irritation of the mucous membranes of the eyes, nose and upper respiratory tract.

EXHIBIT 4.9: AREAS OF FLUORIDES CONCENTRATIONS THAT EXCEED THRESHOLD LEVELS AS A RESULT OF EMISSIONS FROM REGULATION 308 SOURCES ALONE



The reduced cancer mortality is estimated using the Massachusetts unit risk factor. The results indicate a negligible reduction in cancer mortality under all scenarios.

The ambient air standard included in the proposed revisions to Regulation 308 is 65 micrograms per cubic metre averaged over one hour. We converted this proposed standard to 5.42 micrograms per cubic metre as an annual average. Concentrations due to emissions from Regulation 308 Sources do not exceed this proposed standard.

The areas exposed to concentrations of formaldehyde from Regulation 308 Source emissions are displayed in Exhibit I.51 (Appendix I). The profiles of formaldehyde concentration due to emissions by Regulation 308 Sources by scenario are shown in Exhibit I.52.

4.29 Hydrogen Chloride

Hydrogen chloride readily dissolves in water, producing hydrochloric acid. This is irritating to the eyes, nose and throat.

Hydrogen chloride is also a corrosive gas. The ambient air standard of 40 micrograms per cubic metre averaged over 24 hours included in the proposed revisions to Regulation 308 is intended to protect materials from corrosion. We converted this proposed standard to 8 micrograms per cubic metre as an annual average.

The proposed ambient air quality standard is not exceeded by concentrations due to Regulation 308 Source emissions. We were not able to estimate the benefits of reduced emissions on materials damage.

There is some indication that the proposed ambient air standard may not provide adequate protection to vegetation (see Appendix C). The agricultural area exposed to hydrogen chloride emissions from Regulation 308 Sources is estimated at 2,863 square kilometers (8 percent of Ontario's cropland). None of these areas are exposed to hydrogen chloride concentrations in excess of the proposed standard due to Regulation 308 sources.

The areas exposed to hydrogen chloride emissions from Regulation 308 Sources are displayed in Exhibit I.53 (Appendix I). Most of the areas are urban rather than agricultural. The profiles of hydrogen chloride concentration due to emissions from Regulation 308 Sources under each scenario are shown in Exhibit I.54.

4.30 Lead

Lead is not considered carcinogenic, but it can have serious health effects.

The proposed revisions to Regulation 308 include three different ambient air quality standards for lead, based on different averaging times and calculations. For the analysis we used a standard of 5 micrograms per cubic metre averaged over 24 hours. We converted this proposed standard to 1 microgram per cubic metre as an annual average.

The estimated concentrations due to emissions from Regulation 308 Sources exceed the proposed standard at present. The above threshold concentrations occur in 8 grid cells for a total area of 128 km^2 and a total population of approximately 11,000. These occurrences are eliminated by the proposed revisions to Regulation 308 under all scenarios.

Monitoring data suggest that ambient concentrations of lead due to non-Regulation 308 Sources in areas affected by Regulation 308 Source emissions are less than 0.5 micrograms per cubic metre as an annual average. When this maximum value is added to the estimated concentrations due to Regulation 308 Source emissions the ambient concentrations from all sources exceed the proposed standard at present in 20 grid cells with a total area of 320 km^2 and a total population of almost 28,000. As shown in Exhibit 4.10, the proposed revisions to Regulation 308 are effective in eliminating these above threshold occurrences under all scenarios.

The areas affected by lead emissions from Regulation 308 Sources are shown in Exhibit I.55 (Appendix I). The profiles of lead concentration due to emissions by Regulation 308 Sources by scenario are shown in Exhibit I.56.

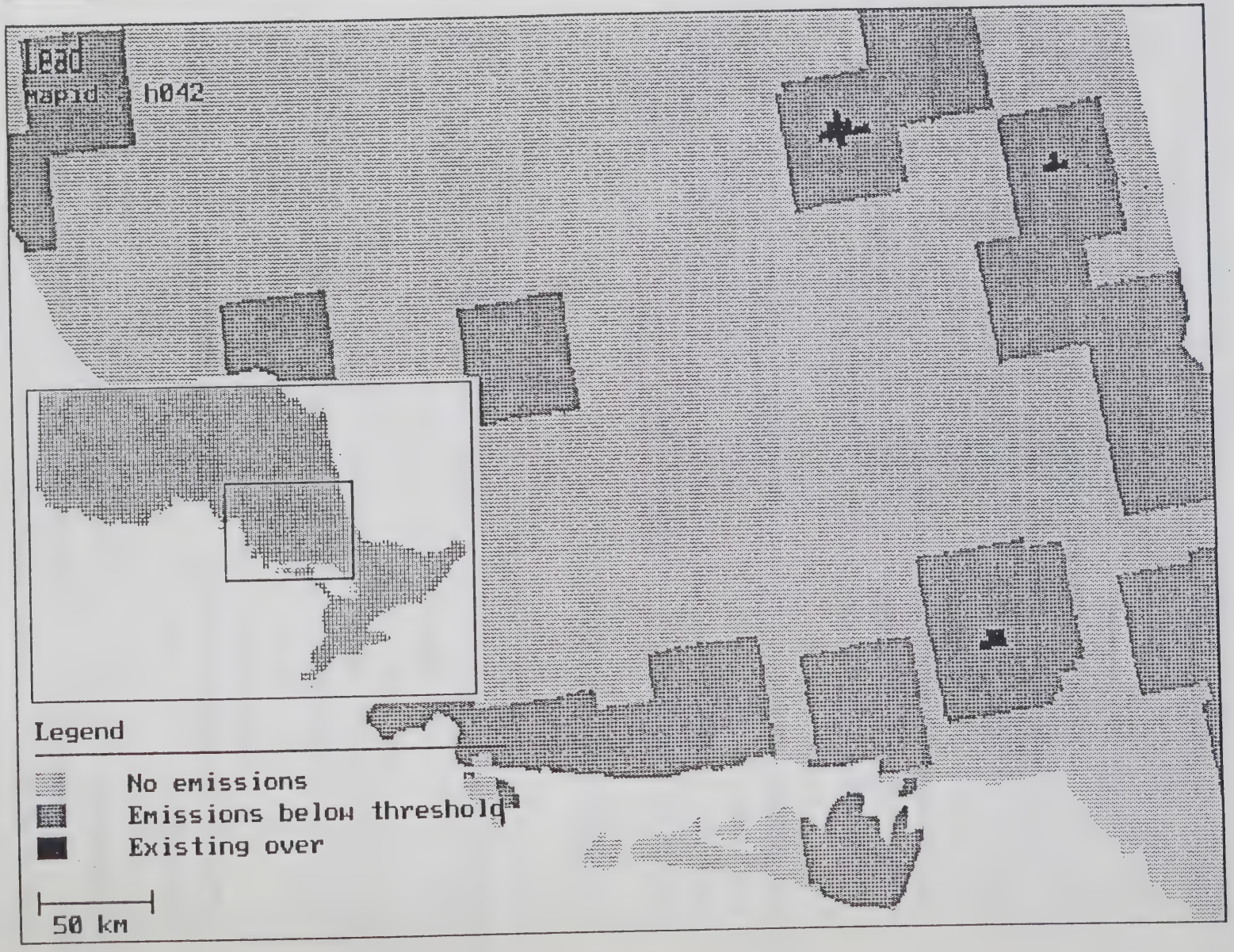
4.31 Manganese Compounds

Manganese is not considered carcinogenic to humans. Chronic manganese exposure results in damage to the central nervous systems and the lungs.

The ambient air quality standard included in the proposed revisions to Regulation 308 is 10 micrograms per cubic metre averaged over 24 hours. We expressed this as an annual average of 2.0 micrograms per cubic metre. The estimated concentrations due to emissions from Regulation 308 Sources do not exceed this standard.

Monitoring data indicate that ambient concentration of manganese due to non-Regulation 308 Sources in the areas affected by Regulation 308 Source emissions is a maximum of 0.15 micrograms per cubic metre as a annual average. When this value is added to the estimated concentrations due to Regulation 308 Source

EXHIBIT 4.10: AREAS OF LEAD CONCENTRATIONS THAT EXCEED THRESHOLD LEVELS AS A RESULT OF EMISSIONS FROM ALL SOURCES



emissions the threshold value still is not exceeded. Thus, the revisions to Regulation 308 do not result in a health benefit in the form of fewer people exposed to above threshold concentrations of manganese.

The areas of manganese exposure due to emissions from Regulation 308 Sources are shown in Exhibit I.57 (Appendix I). The profiles of manganese concentration due to emissions by Regulation 308 Sources by scenario are shown in Exhibit I.58.

4.32 Mercury

Acute exposures to high concentrations of mercury cause bronchitis. Chronic exposure results in a variety of serious health effects: bronchial irritation, bronchitis and diffuse interstitial pneumonitis. Chronic exposure results in weight loss and minor central nervous system symptomatology, psychotic disturbances, and personality changes. Mercury is not associated with any form of cancer in humans.

The ambient air quality standard included in the proposed revisions to Regulation 308 is 2 micrograms per cubic metre averaged over 24 hours. For the purposes of the analysis we expressed this as 0.4 micrograms per cubic metre as an annual average. Concentrations estimated from emissions due to Regulation 308 Sources do not exceed the proposed standard.

The areas affected by the mercury emissions from Regulation 308 Sources are shown in Exhibit I.59 (Appendix I). The profiles of mercury concentration due to emissions by Regulation 308 Sources by scenario are presented in Exhibit I.60.

4.33 Methyl Isobutyl Ketone

High vapour concentrations of methyl isobutyl ketone produce eye and throat symptoms. Narcosis also occurs with additional symptoms of weakness, headache, nausea, lightheadedness, vomiting, dizziness and incoordination. It is not considered carcinogenic.

The ambient air quality standard included in the proposed revisions to Regulation 308 is based on the odour threshold. It is 1,200 micrograms per cubic metre averaged over a 24 hour period. We converted this to 240 micrograms per cubic metre as an annual average for the purposes of the analysis.

Concentrations due to emissions from Regulation 308 Sources do not exceed the proposed standard. As noted earlier for 2-butanone the analytical approach, which is based on annual averages, is not well suited to assessing improvements in odour problems. An analysis of the frequency and duration of above threshold concentration occurrences, rather than an analysis of annual average concentrations, is required. In turn, that requires data on the variability of emission rates; data not available at present.

The areas affected by methyl isobutyl ketone emissions from Regulation 308 Sources are displayed in Exhibit I.61 (Appendix I). The profiles of methyl isobutyl ketone concentration due to Regulation 308 Source emissions are presented in Exhibit I.62.

4.34 Methylene Chloride

Methylene chloride is classified as a probable human carcinogen. Exposure may also cause sluggishness, irritability, lightheadedness, nausea and headaches.

The reduced cancer deaths attributable to lower emissions of methylene chloride resulting from implementation of the proposed revisions to Regulation 308 are calculated using the IRIS unit risk factor. The result is a reduction in cancer mortality of much less than one life per year under each scenario.

The proposed revisions to Regulation 308 include an ambient air quality standard of 7,000 micrograms per cubic metre averaged over one hour. We expressed this proposed standard as 583 micrograms per cubic metre as an annual average. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard.

The areas affected by methylene chloride emissions from Regulation 308 Sources are shown in Exhibit I.63 (Appendix I). The profiles of methylene chloride concentration due to Regulation 308 Source emissions by scenario are presented in Exhibit I.64.

4.35 Naphthalene

Naphthalene is not considered a human carcinogen. Naphthalene vapour may cause headache, loss of appetite and nausea.

The proposed revisions to Regulation 308 include an ambient air quality standard of 30 micrograms per cubic metre averaged over one hour, which we converted to 2.5 micrograms per cubic metre as an annual average. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard.

Naphthalene can also cause odour problems. Since there are no areas where naphthalene concentrations exceed the threshold, there are no continuous odour problems. But the frequency and duration of above threshold concentration occurrences can not be

determined. The impact of the proposed revisions to Regulation 308 in ameliorating odour problems also can not be determined.

The areas affected by naphthalene emissions from Regulation 308 Sources are shown in Exhibit I.65 (Appendix I). Profiles of naphthalene concentration due to Regulation 308 Source emissions by scenario are displayed in Exhibit I.66.

4.36 Nickel

Nickel subsulfide is classified as a probable human carcinogen. Inhalation exposure to certain nickel compounds causes asthma and increased susceptibility to pulmonary infections.

The reduced cancer deaths attributable to lower emissions of nickel that would result from implementation of the proposed revisions to Regulation 308 are calculated using the IRIS unit risk factor. The result is a reduction in cancer mortality of less than one life per year under each scenario except Scenario C.

The proposed revisions to Regulation 308 include an ambient air quality standard of 2 micrograms per cubic metre averaged over 24 hours, which we converted to as 0.4 micrograms per cubic metre as an annual average. Concentrations calculated from the estimated emissions of Regulation 308 Sources exceed this standard at present. Approximately 26,000 people in one grid cell are exposed to above threshold concentrations of nickel due to Regulation 308 Sources at present. This falls to zero under all scenarios.

Monitoring data indicate that ambient concentrations of nickel due to non-Regulation 308 Sources in the areas affected by Regulation 308 Source emissions are a maximum of 0.1 micrograms

per cubic metre as an annual average. When this maximum value is added to the concentrations due to Regulation 308 Source emissions the population exposed to above threshold concentrations of nickel rises to 34,000 at present, but falls to zero under all scenarios except Scenario C where it is 26,000. This is shown in Exhibit 4.11.

Since the above threshold concentration only occurs in one grid cell, it could be due to the concentration of source locations at grid points. However, the cell in question is in the Hamilton area and has only 3 sources located at its centroid. In our judgement that is a reasonable depiction of reality; which means that the proposed revisions to Regulation 308 yield a health benefit by eliminating the occurrence of above threshold concentrations (except possibly under Scenario C).

Nickel can also cause crop damage. Emissions from Regulation 308 Sources affect 26,736 km^2 of agricultural crops in Ontario; 78 percent of the province's land under cultivation. However, there are no agricultural areas exposed to above threshold concentrations of nickel from Regulation 308 Sources, even after the maximum concentration due to other sources is added.

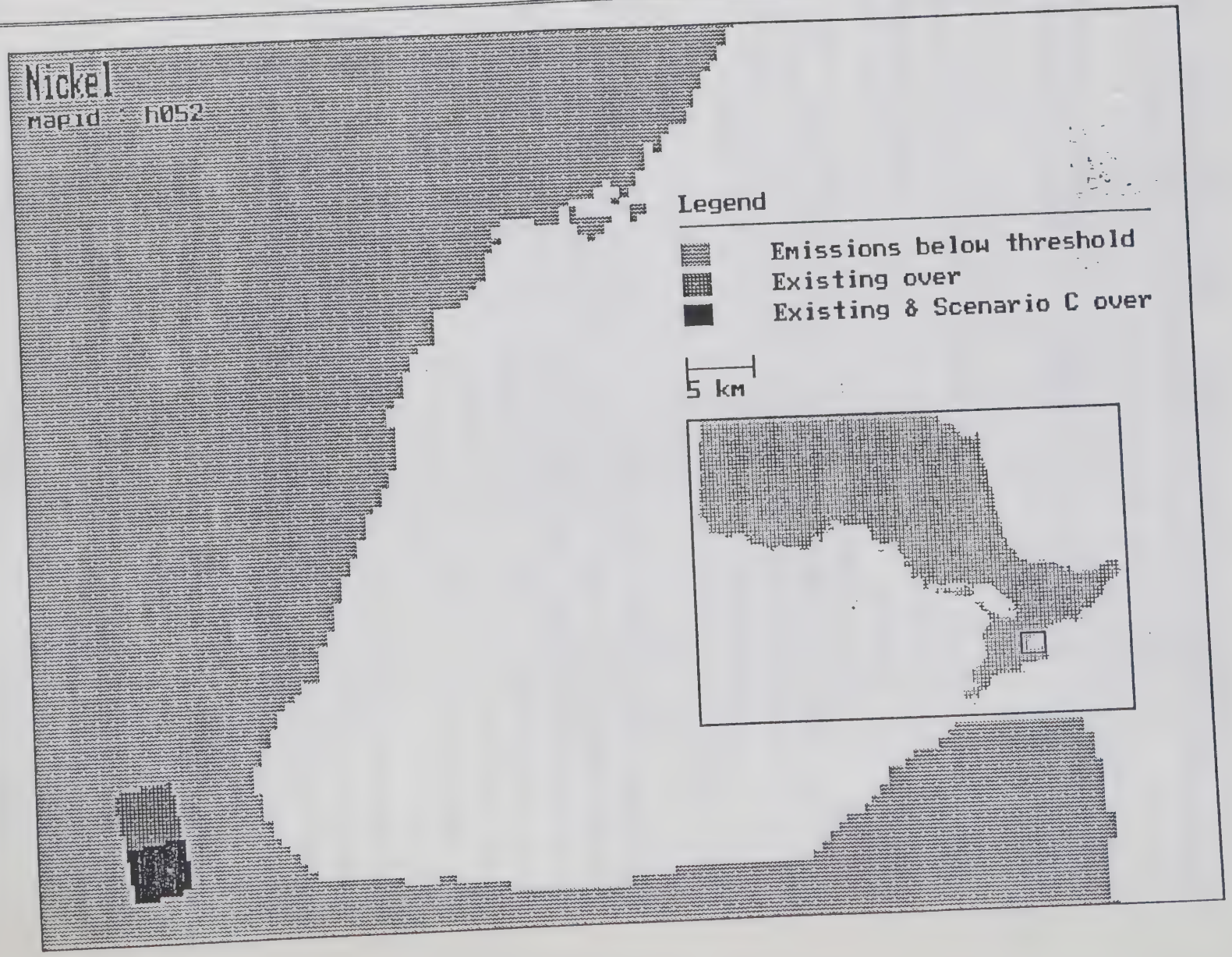
The areas affected by nickel emissions from Regulation 308 Sources are shown in Exhibit I.67 (Appendix I). Profiles of nickel concentration due to Regulation 308 Source emissions by scenario are presented in Exhibit I.68.

4.37 Nitrogen Oxides

Nitrogen oxides are not considered carcinogenic. Exposure may cause eye irritation.

The proposed revisions to Regulation 308 include an ambient air quality standard of 200 micrograms per cubic metre averaged over

EXHIBIT 4.11: AREAS OF NICKEL CONCENTRATIONS THAT EXCEED THRESHOLD LEVELS DUE TO EMISSIONS FROM ALL SOURCES



24 hours, which we converted to 40 micrograms per cubic metre as an annual average for the purposes of our analysis. Analysis of the estimated concentrations due to emissions from Regulation 308 Sources indicates that approximately 1,200 people over 80 km^2 are presently exposed to above threshold concentrations of nitrogen oxides from these sources. This remains unchanged for all scenarios. (See Exhibit 4.12).

Reducing nitrogen oxides emissions also improves visibility and lowers materials damage. The exposure-response functions for visibility and materials damage for nitrogen oxides are presented in Appendix H. Application of those exposure-response functions to the concentrations estimated from Regulation 308 Source emissions under each scenario yields the following results:

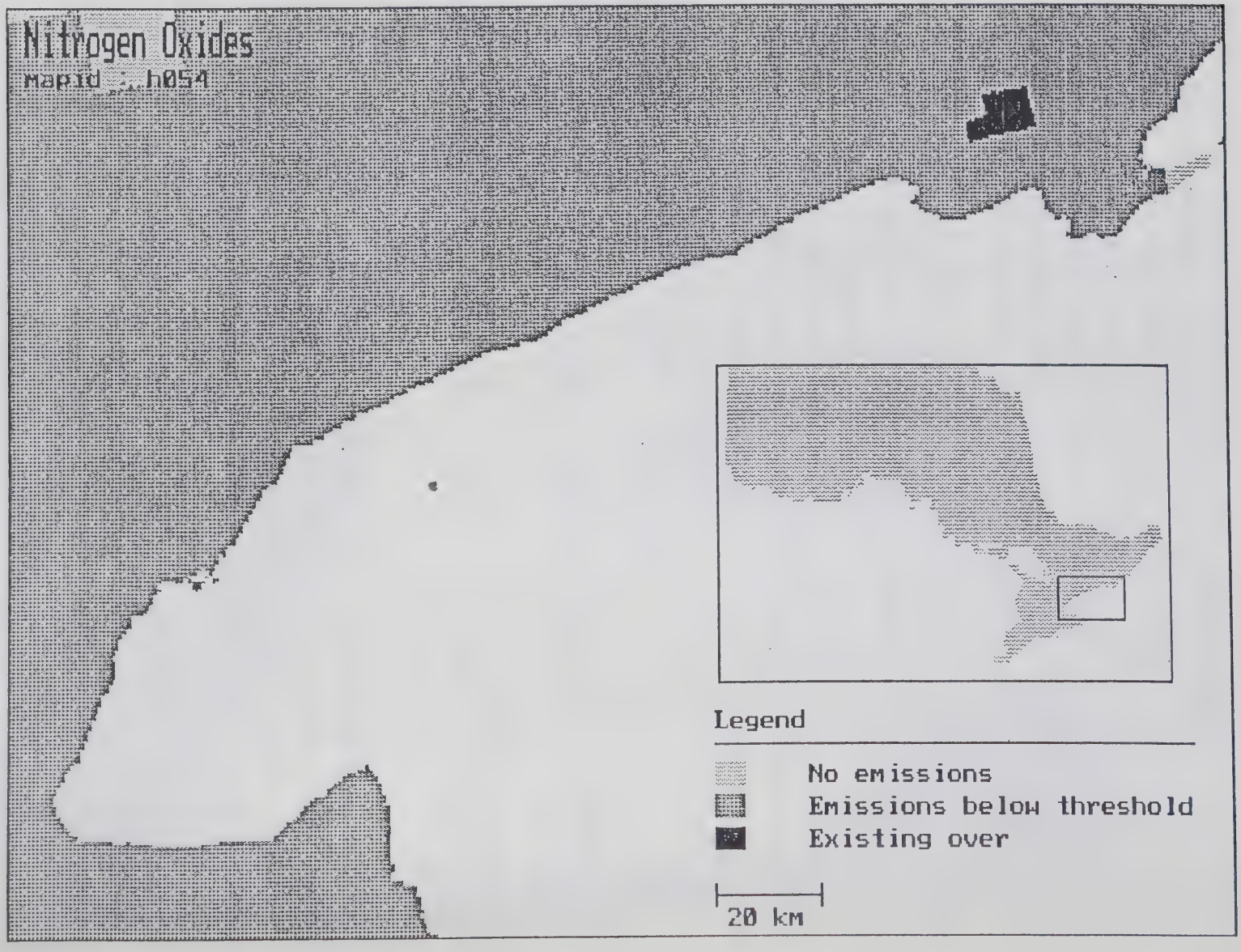
		Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Visibility (million 1986 C$)	Low	$1,249.0	$1,361.4	$ 932.5	$1,013.2
	Central	$2,560.4	$2,790.9	$1,911.6	$2,077.0
Materials Damage (million 1986 C$)	Low	$ 333.2	$ 402.9	$ 234.4	$ 279.7
	Central	$ 666.3	$ 805.8	$ 468.8	$ 559.4

The areas affected by nitrogen oxides emissions from Regulation 308 Sources are shown in Exhibit I.69 (Appendix I). Profiles of nitrogen oxides concentration due to Regulation 308 Source emissions by scenario are presented in Exhibit I.70.

4.38 Perchloroethylene

Perchloroethylene is not considered a carcinogen. Excessive exposure to perchloroethylene has resulted in effects on the central nervous system, mucous membranes, eyes and skin, and to a lesser extent the lungs, liver and kidneys.

EXHIBIT 4.12: AREAS OF NITROGEN OXIDES CONCENTRATIONS THAT EXCEED THRESHOLD LEVELS DUE TO EMISSIONS FROM REGULATION 308 SOURCES ALONE



The proposed revisions to Regulation 308 include an ambient air quality standard of 4,000 micrograms per cubic metre averaged over 24 hours. We converted this to 800 micrograms per cubic metre as an annual average. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard.

This result must be treated with some caution. The principal source of perchloroethylene emissions is dry cleaning establishments and all dry cleaning establishments were assumed to have equal emissions. Thus, if the concentrations due to emissions from one establishment do not exceed the proposed standard, all will meet the standard, unless several are concentrated at one location.

The areas affected by perchloroethylene emissions from Regulation 308 Sources are shown in Exhibit I.71 (Appendix I). Profiles of perchloroethylene concentration due to Regulation 308 Source emissions by scenario are provided in Exhibit I.72.

4.39 Phenol

Phenol does not appear to be carcinogenic. Chronic exposure can result in digestive disturbances, vomiting, diarrhea, and nervous disorders.

The proposed revisions to Regulation 308 include an ambient air quality standard of 100 micrograms per cubic metre averaged over 24 hours. We converted this to 20 micrograms per cubic metre as an annual average. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this proposed standard.

The areas affected by phenol emissions from Regulation 308 Sources are shown in Exhibit I.73 (Appendix I). Profiles of

phenol concentration due to Regulation 308 Source emissions by scenario are provided in Exhibit I.74.

4.40 Polychlorinated Biphenyls (PCB's)

Polychlorinated biphenyls are classified as a probable human carcinogen. Exposure to PCB vapour or fumes may cause acne, irritation of respiratory passage and injury to the liver.

The reduced cancer deaths attributable to lower emissions of polychlorinated biphenyls that would result from implementation of the proposed revisions to Regulation 308 are calculated using the Massachusetts unit risk factor. The reduced cancer mortality is negligible under each scenario.

The proposed revisions to Regulation 308 include an ambient air quality standard of 0.15 micrograms per cubic metre averaged over 24 hours, which we expressed as an annual average of 0.03 micrograms per cubic metre. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard.

The areas affected by polychlorinated biphenyl emissions from Regulation 308 Sources are shown in Exhibit I.75 (Appendix I). Profiles of PCB concentration due to Regulation 308 Source emissions by scenario are provided in Exhibit I.76.

4.41 Propionaldehyde

Propionaldehyde is not considered carcinogenic. Other health effects are not known. The principal concern is odour.

The proposed revisions to Regulation 308 include an ambient air quality standard of 2.5 micrograms per cubic metre averaged over 24 hours, which we converted to 0.5 micrograms per cubic metre as

an annual average. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard.

As discussed earlier for other contaminants that may cause odour problems, this simply means that propionaldehyde odour is not a continuous problem anywhere. We are not able to address the frequency and persistence of odour occurrences, nor the extent to which the proposed revisions to Regulation 308 would relieve such problems.

The areas affected by propionaldehyde emissions from Regulation 308 Sources are shown in Exhibit I.77 (Appendix I). Profiles of propionaldehyde concentration due to emissions by Regulation 308 Sources under each scenario are presented in Exhibit I.78.

4.42 Propionic Acid

Propionic acid is not considered carcinogenic. Acute human exposures cause mild to moderate skin burns and mild eye response.

The proposed revisions to Regulation 308 include an ambient air quality standard of 80 micrograms per cubic metre averaged over one hour. We converted this to an annual average of 6.67 micrograms per cubic metre. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard.

The areas affected by propionic acid emissions from Regulation 308 Sources are shown in Exhibit I.79 (Appendix I). Profiles of propionic acid concentration due to emissions by Regulation 308 Sources under each scenario are presented in Exhibit I.80.

4.43 Propylene Oxide

Propylene oxide is classified as a probable human carcinogen. It is also an irritant to the eyes, skin, respiratory passage and lungs.

The reduced cancer deaths attributable to lower emissions of propylene oxide that would result from implementation of the proposed revisions to Regulation 308 are calculated using the Massachusetts unit risk factor. The reduction in cancer mortality is significantly less than one life per year under each scenario.

The proposed revisions to Regulation 308 include an ambient air quality standard of 4,500 micrograms per cubic metre averaged over 24 hours, which we expressed as 900 micrograms per cubic metre averaged over one year. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard.

The areas affected by propylene oxide emissions from Regulation 308 Sources are shown in Exhibit I.81 (Appendix I). Profiles of propylene oxide concentration due to emission by Regulation 308 Sources under each scenario are displayed in Exhibit I.82.

4.44 Selenium

There is conflicting evidence as to whether selenium is carcinogenic. Exposure to selenium dust has caused catarrh, nose bleeds, and loss of smell. Exposure to fumes has caused frontal headache, intense eye irritation and difficulty breathing.

The proposed revisions to Regulation 308 include an ambient air quality standard of 10 micrograms per cubic metre averaged over

24 hours. We converted this to 2 micrograms per cubic metre as an annual average. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard at present.

Selenium can also cause crop damage. Some 25,689 km^2 of crop land (75% of Ontario's total) are exposed to emissions of selenium from Regulation 308 sources. However, there are no areas where selenium concentrations from these sources exceed the proposed standard.

The areas affected by selenium emissions from Regulation 308 Sources are shown in Exhibit I.83 (Appendix I). Profiles of selenium concentration due to emissions from Regulation 308 Sources by scenario are presented in Exhibit I.84.

4.45 Silica

Silica is not considered carcinogenic. Exposure to respirable silica causes silicosis.

The proposed revisions to Regulation 308 include an ambient air quality standard of 5 micrograms per cubic metre averaged over 24 hours, which we converted to 1 microgram per cubic metre as an annual average. Concentrations calculated from the estimated emissions of Regulation 308 Sources exceed this standard.

The area and population exposed to above threshold concentrations of silica as a result of Regulation 308 Source emissions are as follows:

	Area (km^2)	Population	Change from Current Area	Change from Current Population
Current	1600	645,000	-	-
Scenarios "A" & "D"	320	129,000	-80%	-80%
Scenario "B"	176	83,000	-89%	-87%
Scenario "C"	608	288,000	-62%	-55%
Scenario "E"	576	238,000	-64%	-63%

The proposed revisions to Regulation 308 do not succeed in reducing silica concentrations due to Regulation 308 Sources alone below the proposed threshold value in all areas of the province. The areas with above threshold concentrations are located in Kirkland Lake, Mississauga, Sarnia and Timmins as shown in Exhibit 4.13.

The areas affected by silica emissions from Regulation 308 Sources are shown in Exhibit I.85 (Appendix I). Profiles of silica concentration due to emissions from Regulation 308 Sources by scenario are presented in Exhibit I.86.

4.46 Styrene

Styrene is classified as a probable human carcinogen. Styrene causes irritation of eyes, nose, and throat and, at higher concentrations, nausea, headache, decreased coordination and a sense of inebriation.

The reduced cancer deaths attributable to lower emissions of styrene that would result from implementation of the proposed revisions to Regulation 308 are calculated using the Massachusetts unit risk factor. The estimated reduction in cancer deaths is negligible.

The proposed revisions to Regulation 308 include an ambient air quality standard of 400 micrograms per cubic metre averaged over

EXHIBIT 4.13: AREAS OF SILICA CONCENTRATIONS THAT EXCEED THRESHOLD LEVELS DUE TO EMISSIONS FROM REGULATION 308 SOURCES ALONE

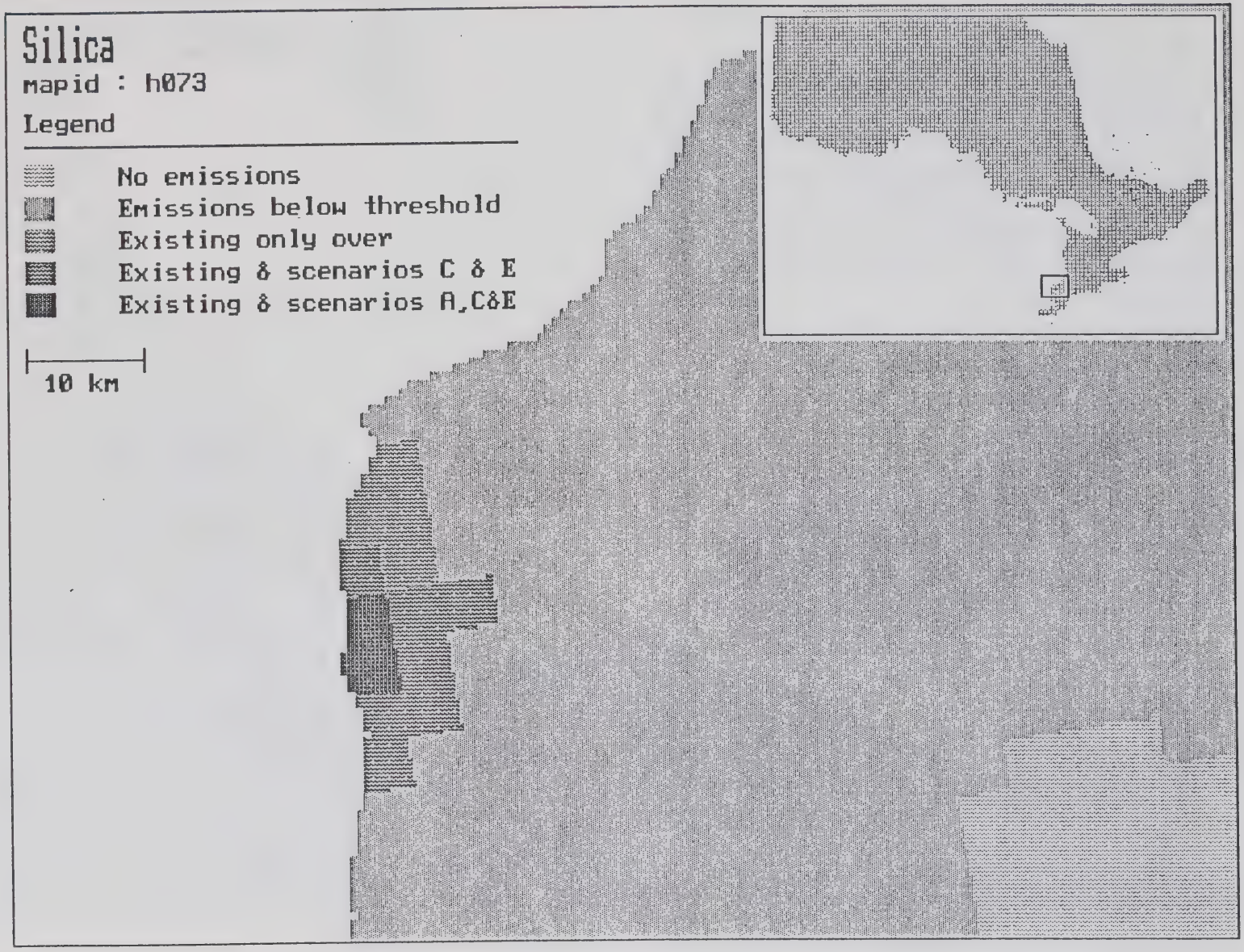


EXHIBIT 4.13: AREAS OF SILICA CONCENTRATIONS THAT EXCEED THRESHOLD LEVELS DUE TO EMISSIONS FROM REGULATION 308 SOURCES ALONE (Continued)

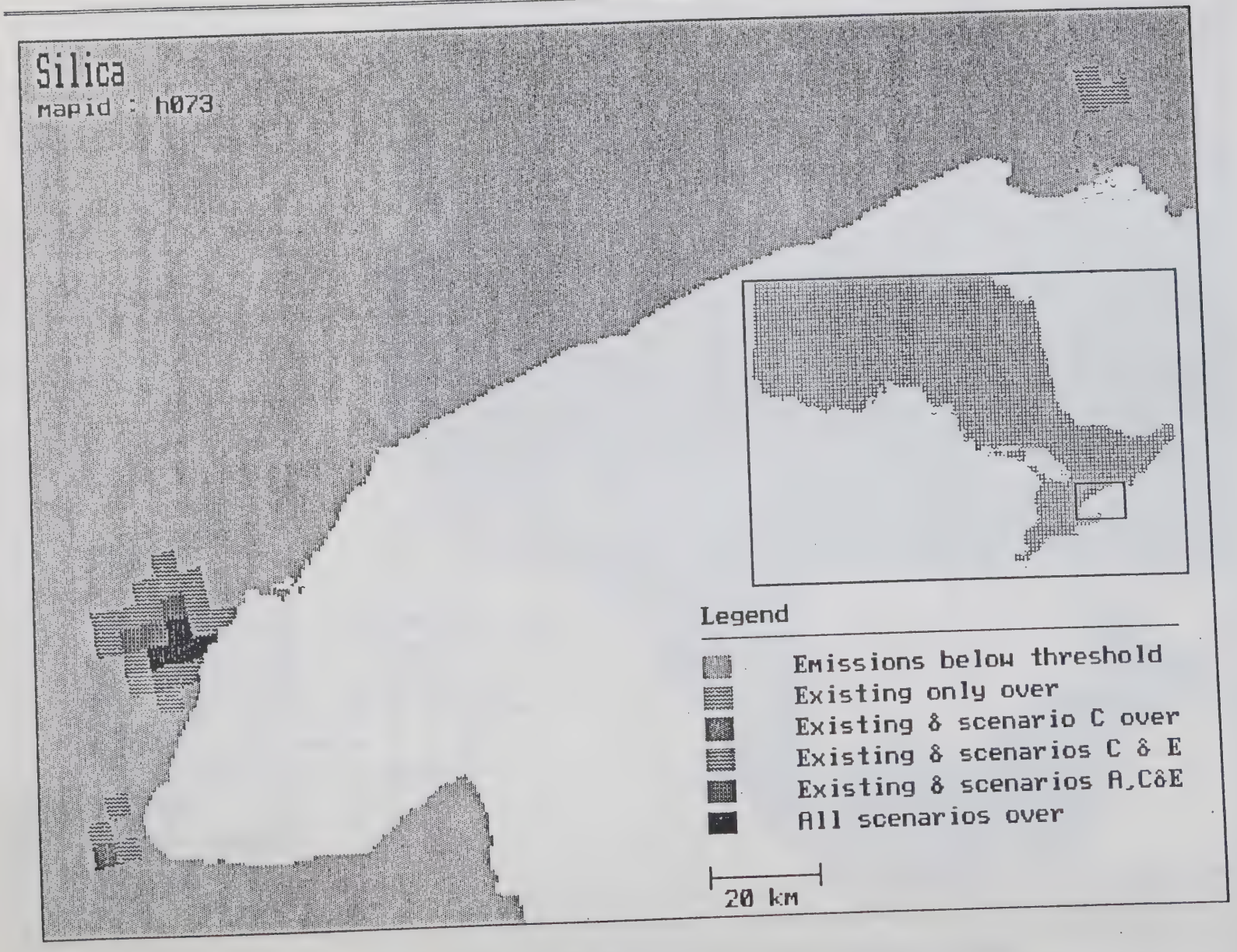


EXHIBIT 4.13: AREAS OF SILICA CONCENTRATIONS THAT EXCEED THRESHOLD LEVELS DUE TO EMISSIONS FROM REGULATION 308 SOURCES ALONE (Continued)

24 hours, which we converted to an annual average of 80 micrograms per cubic metre. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard.

Styrene also gives rise to odour problems. The fact that concentrations do not exceed the proposed threshold indicates that Regulation 308 Sources are not enduring odour problems. However, the frequency and duration of odour problems, as well as the effect of the proposed revisions to Regulation 308 in reducing these problems, can not be determined.

The areas affected by styrene emissions from Regulation 308 Sources are displayed in Exhibit I.87 (Appendix I). Profiles of styrene concentration due to Regulation 308 Sources emissions by scenario are presented in Exhibit I.88.

4.47 Sulphur Dioxide

Sulphur dioxide is not considered carcinogenic. It causes respiratory problems, is phytotoxic, causes materials damage, and can reduce visibility.

The proposed revisions to Regulation 308 include an ambient air quality standard of 275 micrograms per cubic metre averaged over 24 hours, which we converted to 55 micrograms per cubic metre as an annual average. Concentrations calculated from the estimated emissions of Regulation 308 Sources exceed this standard.

The population and areas exposed to above threshold concentrations of sulphur dioxide due to Regulation 308 Source emissions alone are estimated as follows:

	Area (km^2)	Population	Change from Current Area	Change from Current Population
Current	64	12,000	-	-
Scenarios "A" & "D"	16	**	-75%	-100%
Scenario "B"	16	**	-75%	-100%
Scenario "C"	32	12,000	-50%	0%
Scenario "E"	32	12,000	-50%	0%

** = less than 500

Monitoring data for sulphur dioxide indicate that the concentrations due to non-Regulation 308 Sources in the areas affected by Regulation 308 emissions are less than 12 micrograms per cubic metre as an annual average in all cases. When this value is added to the estimated concentrations due to Regulation 308 Sources the above figures are the same, except for the current situation. The population currently exposed to concentrations above the proposed standard due to sulphur dioxide emissions from all sources is 67,000.

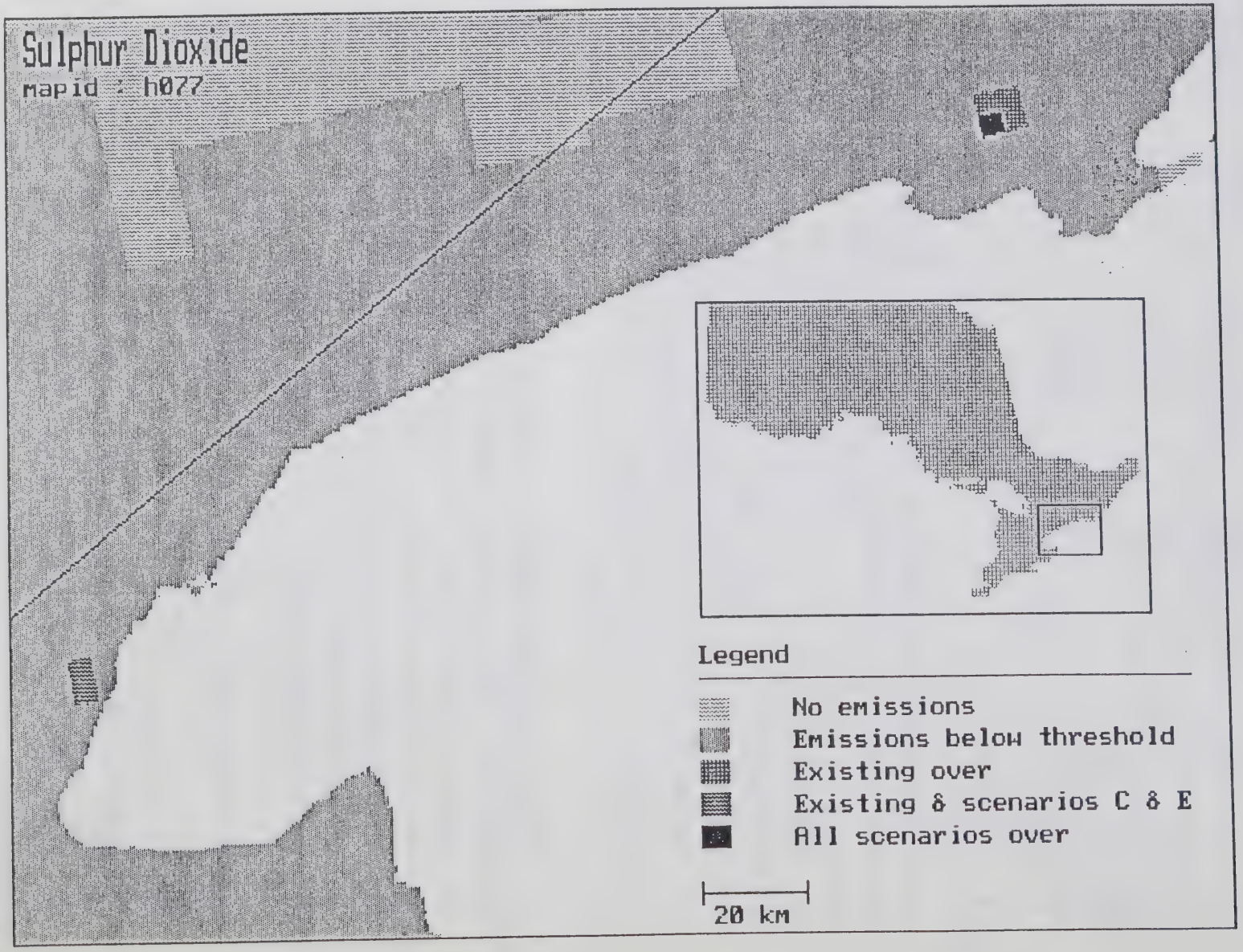
The areas affected by above threshold concentrations of sulphur dioxide are in the "golden horseshoe" as shown in Exhibit 4.14. The results indicate that the proposed revisions to Regulation 308 would be effective in virtually eliminating above threshold exposures to sulphur dioxide under scenarios A, B and D. Scenarios C and E would have little impact on the reducing exposures to above threshold concentrations.

Exposure-response functions for sulphur dioxide are provided in Appendix H with respect to:

- mortality;
- hospital days for respiratory conditions; and
- hospital admissions for respiratory disease.

Reductions in mortality estimated to result from lower concentrations of sulphur dioxide attributable to implementation

EXHIBIT 4.14: AREAS OF SULPHUR DIOXIDE CONCENTRATIONS THAT EXCEED THRESHOLD LEVELS DUE TO EMISSIONS FROM ALL SOURCES



of the proposed revisions to Regulation 308 are estimated as follows:

	Reduced Mortality Deaths/Year	Range of Economic Benefits/Year (1986 C$)
Scenarios "A" & "D"	250	$550 - 1,738 million
Scenario "B"	300	$660 - 2,085 million
Scenario "C"	97	$213 - 674 million
Scenario "E"	97	$213 - 674 million

The estimated benefits of the proposed revisions to Regulation 308 in the form of reduced hospitalization due to lower sulphur dioxide concentrations are as follows:

	Scenarios "A & D"	Scenario "B"	Scenario "C"	Scenario "E"
Hospital Days for Respiratory Conditions	3,746	4,495	1,458	1,458
Hospital Admissions for Respiratory Disease	381	457	148	148
Value (million 1986 C$)				
. Low	$2.5	$3.0	$1.0	$1.0
. Central	$8.7	$10.4	$3.4	$3.4

In addition to being a health hazard, sulphur dioxide is phytotoxic. Emissions from Regulation 308 sources affect 18,438 km^2, 54 percent of the area under cultivation in the province. However, all of the areas where above threshold concentrations occur are urban. No agricultural areas are exposed to above threshold concentrations of sulphur dioxide.

The areas affected by sulphur dioxide emissions from Regulation 308 Sources are shown in Exhibit I.89 (Appendix I). Profiles of sulphur dioxide concentrations due to Regulation 308 Source emissions by scenario are presented in Exhibit I.90.

4.48 Suspended Particulate Matter

Suspended particulate matter is not considered carcinogenic. Suspended particulate matter does cause respiratory problems, damages materials and reduce visibility.

The proposed revisions to Regulation 308 include an ambient air quality standard of 120 micrograms per cubic metre averaged over 24 hours or 60 micrograms per cubic metre as an annual average, calculated as a geometric mean. The proposed standard of 120 micrograms per cubic metre over 24 hours was converted to a annual (arithmetic) average of 24 micrograms per cubic metre. Concentrations calculated from the estimated emissions of Regulation 308 Sources exceed this standard.

The population exposed to above threshold concentrations of suspended particulate matter due to emissions from Regulation 308 Sources alone are estimated as follows:

	Area (km^2)	Population	Change from Current Area	Change from Current Population
Current	240	159,000	-	-
Scenarios "A" & "D"	48	22,000	-80%	-86%
Scenario "B"	16	**	-93%	-100%
Scenario "C"	144	95,000	-40%	-40%
Scenario "E"	80	45,000	-67%	-72%

** = less than 500

The proposed revisions to Regulation 308 achieve a significant reduction in the exposures to above threshold concentrations of suspended particulate matter due to Regulation 308 Source emissions. The reductions under Scenario C are much smaller than those under the other scenarios because it is less stringent.

Monitoring data are available for suspended particulate matter. The monitoring results indicate that the proposed standard of 60 micrograms per cubic metre is exceeded at many stations. When the estimated concentrations due to Regulation 308 Sources emissions are subtracted from the monitoring results, the "residuals" at several stations still exceed the proposed threshold. Thus, we can not use the approach employed for other contaminants where monitoring data are available. In this case adding the maximum "residual" value to all Regulation 308 Source concentrations would put all areas over the threshold because the maximum residual exceeds the threshold. We had no basis for selecting any other single or set of residual values.

However, it is clear that current particulate matter concentrations from all sources exceed the proposed threshold in many areas. The concentrations due to Regulation 308 source emissions alone exceed the proposed threshold in Mississauga and Timmins (see Exhibit 4.15). And the proposed revisions to Regulation 308 will not be sufficient to eliminate the above threshold occurrences attributable to the controlled sources.

Exposure-response functions for suspended particulate matter are available for:

- mortality;
- restricted activity days;
- emergency room visits;
- materials damage; and
- visibility.

These functions are described in Appendix H.

Reductions in mortality estimated to result from lower concentrations of suspended particulate matter attributable to implementation to the proposed revisions to Regulation 308 are estimated as follows:

EXHIBIT 4.15: AREAS OF SUSPENDED PARTICULATE MATTER CONCENTRATIONS THAT EXCEED THRESHOLD LEVELS DUE TO EMISSIONS FROM REGULATION 308 SOURCES ALONE

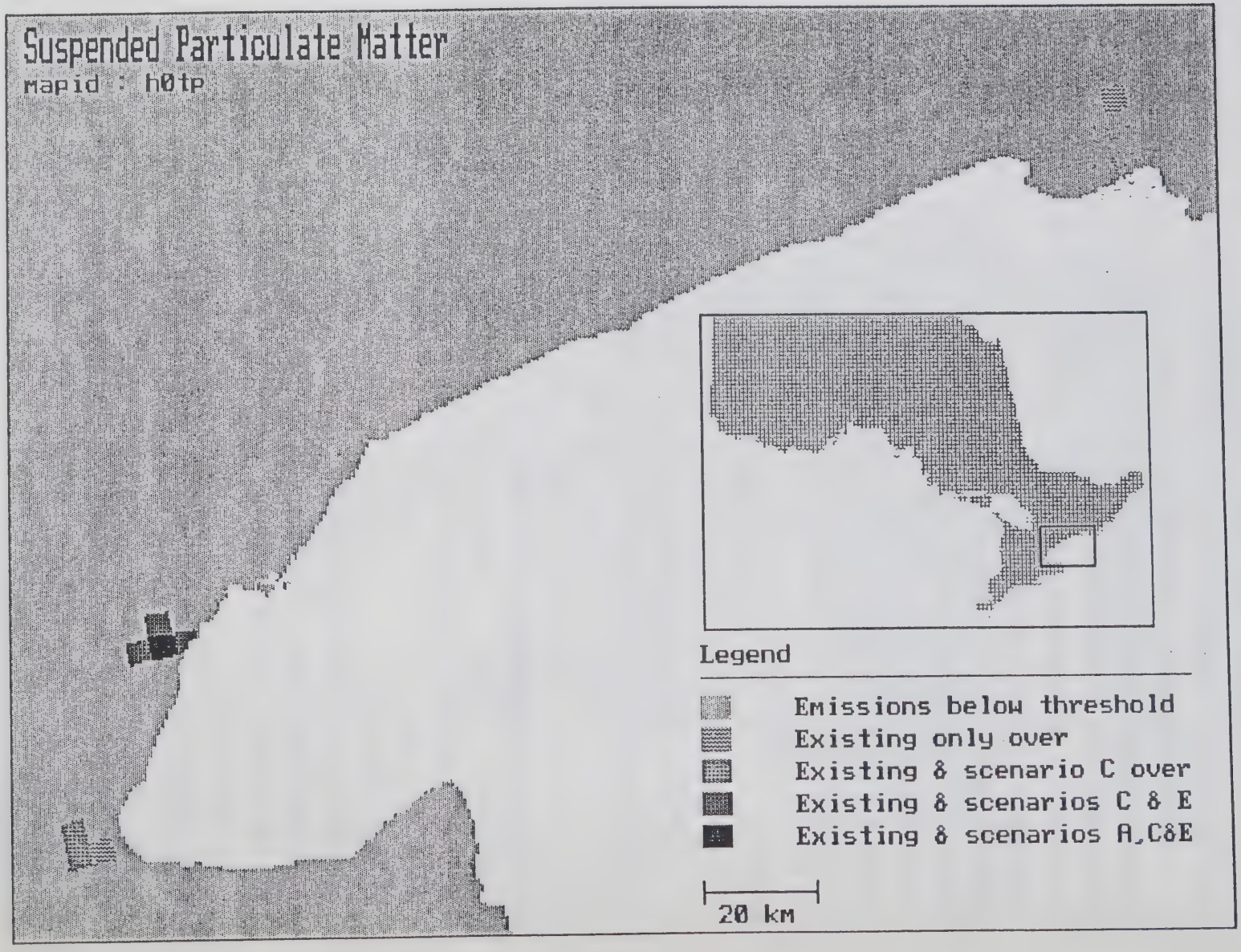
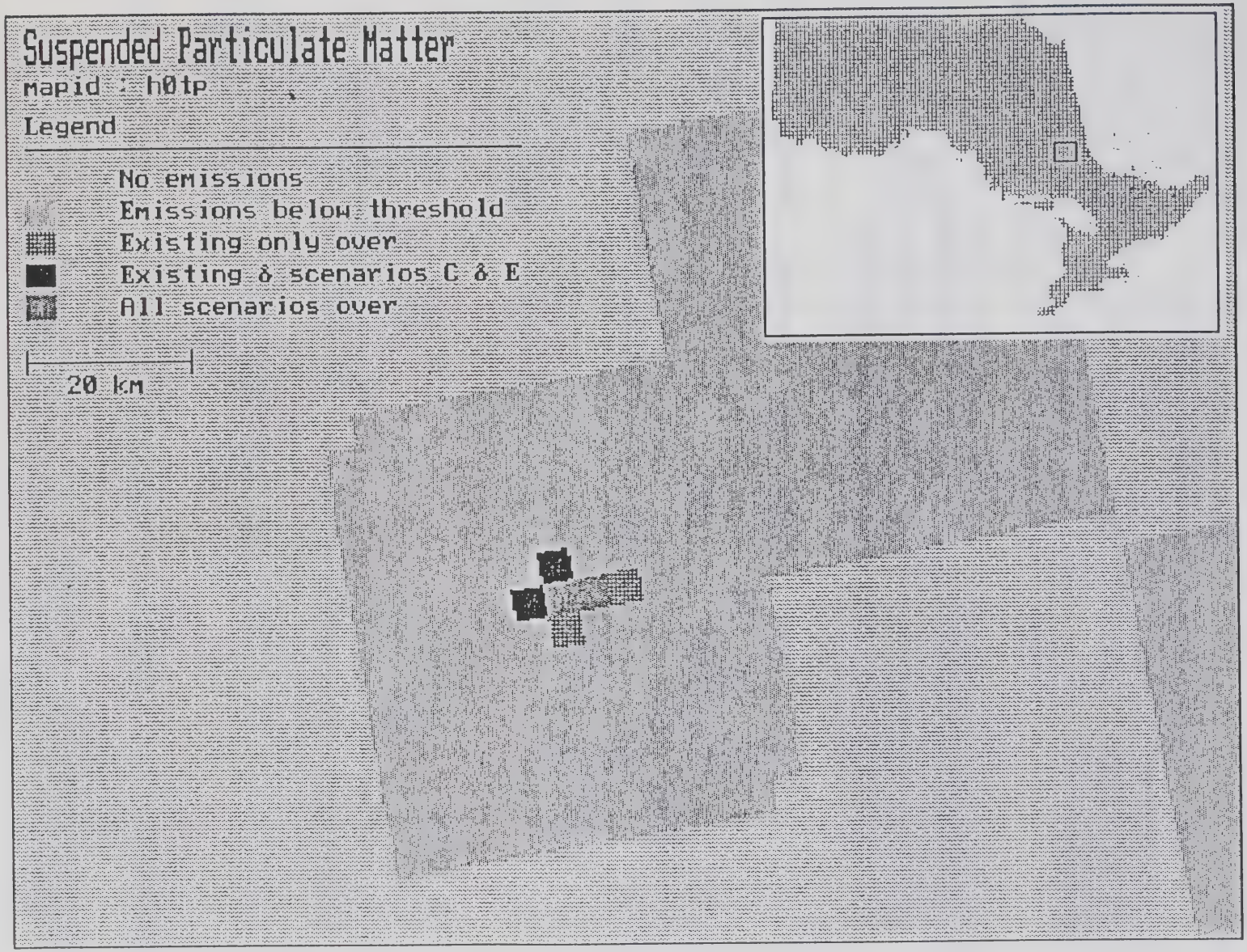


EXHIBIT 4.15: AREAS OF SUSPENDED PARTICULATE MATTER CONCENTRATIONS THAT EXCEED THRESHOLD LEVELS DUE TO EMISSIONS FROM REGULATION 308 SOURCES ALONE



	Reduced Mortality Deaths/Year	Range of Economic Benefits/Year (1986 C$)
Scenarios "A" & "D"	50	$110 - 348 million
Scenario "B"	54	$119 - 375 million
Scenario "C"	25	$ 55 - 174 million
Scenario "E"	36	$ 79 - 250 million

The benefits of implementing the proposed revisions to Regulation 308 in the form of lower restricted activity days and emergency room visits due to reduced particulate matter concentrations are estimated to be as follows:

	Scenarios "A & D"	Scenario "B"	Scenario "C"	Scenario "E"
Emergency Room Visits	2,940	3,188	1,492	2,117
Restricted Activity Days	616,000	668,000	313,000	443,000
Value (million 1986 C$)				
. Low	$6.6	$7.2	$3.4	$4.7
. Central	$37.7	$40.9	$19.2	$27.1

The improved visibility and reduced materials damage estimated to result from lower concentrations of particulate matter attributable to implementation of the proposed revisions to Regulation 308 are as follows:

		Scenarios "A" & "D"	Scenario "B"	Scenario "C"	Scenario "E"
Visibility (million 1986 C$)	Low	$ 653.2	$ 700.2	$ 328.4	$ 583.4
	Central	$1,306.3	$1,400.3	$ 656.7	$1,166.8
Materials Damage (million 1986 C$)	Low	$ 5.8	$ 6.5	$ 2.9	$ 4.2
	Central	$ 83.0	$ 92.5	$ 42.1	$ 59.8

The materials damage benefit is only a partial estimate. It covers only the benefits to households of reduced soiling. The central value for Scenario B represents less than $30 per household per year, an amount that seems quite achievable as an annual saving in dry cleaning and other household cleaning costs. Other types of materials damage and other groups are excluded from the estimates.

The areas affected by suspended particulate matter emissions from Regulation 308 Sources are shown in Exhibit I.91 (Appendix I). Profiles of particulate matter concentration due to emissions from Regulation 308 Sources by scenario are presented in Exhibit I.92.

4.49 Tin

Tin is not considered carcinogenic. Tin salts are highly toxic after they have gained access to the blood stream, causing paralysis and other neurologic damage. Organic tin compounds have been linked to skin irritation and effects on the central nervous system and circulatory system.

The proposed revisions to Regulation 308 include an ambient air quality standard of 10 micrograms per cubic metre averaged over 24 hours, which we expressed as 2 micrograms per cubic metre averaged over a year. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard.

The areas affected by tin emissions from Regulation 308 Sources are shown in Exhibit I.93 (Appendix I). Profiles of tin concentration due to Regulation 308 source emissions by scenario are presented in Exhibit I.94.

4.50 Toluene

Toluene does not appear to be carcinogenic. Acute exposure may cause mental confusion, dizziness and inappropriate behaviour.

The proposed revisions to Regulation 308 include an ambient air quality standard of 2,000 micrograms per cubic metre averaged over 24 hours, which we converted to 400 micrograms per cubic metre as an annual average. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard.

The areas affected by toluene emissions from Regulation 308 Sources are shown in Exhibit I.95 (Appendix I). Profiles of toluene concentration due to emissions from Regulation 308 Sources by scenario are presented in Exhibit I.96.

4.51 Toluene Diisocyanate

Toluene diisocyanate is classified as a probable human carcinogen. Acute exposure to vapour can produce severe irritant effects on mucous membranes, the respiratory tract and the eyes.

The reduced cancer deaths attributable to lower emissions of toluene diisocyanate that would result from implementation of the proposed revisions to Regulation 308 are calculated using the Massachusetts unit risk factor. The reduction in cancer mortality is significantly less than one life per year under each scenario.

The proposed revisions to Regulation 308 include an ambient air quality standard of 0.5 micrograms per cubic metre averaged over 24 hours, which we expressed as 0.1 micrograms per cubic metre as an annual average. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard.

The areas affected by toluene diisocyanate emissions from Regulation 308 Sources are shown in Exhibit I.97 (Appendix I). Profiles of toluene diisocyanate concentration due to emissions from Regulation 308 Sources by scenario are presented in Exhibit I.98.

4.52 1,1,1-Trichloroethane (Methyl Chloroform)

1,1,1-trichloroethane is a suggested human carcinogen. Other human health effects are not well known.

The reduced cancer deaths attributable to lower concentrations of 1,1,1-trichloroethane that would result from implementation of the proposed revisions to Regulation 308 are calculated using the Massachusetts unit risk factor. The reduced cancer mortality due to the proposed revisions to Regulation 308 is insignificant.

The proposed revisions to Regulation 308 include an ambient air quality standard of 115,000 micrograms per cubic metre averaged over 24 hours, which we converted to 23,000 micrograms per cubic metre as an annual average. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard.

The areas affected by 1,1,1-trichloroethane emissions from Regulation 308 Sources are shown in Exhibit I.99 (Appendix I). Profiles of 1,1,1-trichloroethane concentrations due to emissions from Regulation 308 Sources by scenario are presented in Exhibit I.100.

4.53 Trichlorobenzenes

We selected 1,3,5-trichlorobenzene to represent trichlorobenzenes generally. It is not considered carcinogenic,

but is moderately irritating to the skin and has been associated with liver injury and hair loss.

The proposed revisions to Regulation 308 include a proposed ambient air quality standard of 35 micrograms per cubic metre averaged over 24 hours for 1,2,4-trichlorobenzene. We converted this to 7 micrograms per cubic metre as an annual average and used it as the health threshold. Concentrations calculated from estimated emissions of Regulation 308 Sources do not exceed this proposed standard.

The areas affected by emissions of trichlorobenzenes from Regulation 308 Sources are shown in Exhibit I.101 (Appendix I). Profiles of trichlorobenzene concentration due to emissions from Regulation 308 Sources by scenario are presented in Exhibit I.102.

4.54 Trichloroethylene

Trichloroethylene is classified as a probable human carcinogen. Inhaled trichloroethylene attacks the central nervous system, liver, kidney and haematological system.

The reduced cancer deaths attributable to lower emissions of trichloroethylene that would result from implementation of the proposed revisions to Regulation 308 are calculated using the IRIS unit risk factor. The reduced cancer mortality is significantly less than one life per year under each scenario.

The proposed revisions to Regulation 308 include an ambient air quality standard of 28,000 micrograms per cubic metre averaged over 24 hours, which we converted to 5,600 micrograms per cubic metre as an annual average. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard.

Trichloroethylene also gives rise to odour problems. Since the trichloroethylene concentrations do not exceed the proposed standard, there are no persistent odour problems due to Regulation 308 Sources. However, the frequency and duration of odour problems, as well as the effect of the proposed revisions to Regulation 308 in reducing these problems, can not be determined.

The areas affected by trichloroethylene emissions from Regulation 308 Sources are shown in Exhibit I.103 (Appendix I). Profiles of trichloroethylene concentration due to Regulation 308 Source emissions by scenario are provided in Exhibit I.104.

4.55 Vinyl Chloride

Vinyl chloride is classified as a probable human carcinogen. Short term acute exposures may cause dizziness, headache, unconsciousness and death.

The reduced cancer deaths attributable to lower emissions of vinyl chloride that would result from implementation of the proposed revisions to Regulation 308 are calculated using the Massachusetts unit risk factor. The reduction in cancer mortality is significantly less than one life per year under each scenario.

The proposed revisions to Regulation 308 include an ambient air quality standard of 280 micrograms per cubic metre averaged over 24 hours, which we converted to 56 micrograms per cubic metre as an annual average. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard.

The areas affected by vinyl chloride emissions from Regulation 308 Sources are shown in Exhibit I.105 (Appendix I).

Profiles of vinyl chloride concentration due to Regulation 308 Source emissions by scenario are presented in Exhibit I.106.

4.56 Xylenes

Xylenes are not considered carcinogenic. Low concentrations cause irritation to eyes, nose and throat. Higher concentrations may cause dizziness, nausea and unconsciousness.

The proposed revisions to Regulation 308 include an ambient air quality standard of 2,300 micrograms per cubic metre averaged over 24 hours, which we expressed as 460 micrograms per cubic metre averaged over a year. Concentrations calculated from the estimated emissions of Regulation 308 Sources do not exceed this standard.

The areas affected by xylenes emissions from Regulation 308 Sources are shown in Exhibit I.107 (Appendix I). Profiles of xylenes concentration due to Regulation 308 Source emissions by scenario are presented in Exhibit I.108.

5.0 SUMMARY AND CONCLUSIONS

5.1 Introduction

This chapter presents a summary of our results, some interpretation of those results, and suggestions for future refinements.

The public benefits associated with the proposed revisions to Regulation 308 relate primarily to human health. This is not surprising in that:

- most of the emission sources are located in urban areas;
- the contaminants of concern are identified primarily because of their potential impact on human health; and
- research into the effects of contaminants focuses first on human health, so those are the benefits for which the best information is available.

Some of the major known sources of damage to other environmental resources, such as ozone, nitrogen dioxide and sulphates, play only a minor role in this study. The largest sources of nitrogen dioxide and sulphate emissions fall under the acid rain initiative and hence outside the purview of this analysis. Ozone, because it is formed in the atmosphere rather than emitted, also is not addressed in this study.

We stress again that this analysis is a broad overview of the public benefits of the proposed revisions to Regulation 308. It is inevitable that in a broad overview many of the details will be somewhat fuzzy. The suggestions for future refinements are generally designed to better understand such details. That will

gradually yield a better overall picture of the public benefits of improved air quality.

5.2 Reduced Mortality

5.2.1 Cancer Mortality

Many of the 96 contaminants analysed are suspected, probable or known carcinogens. Emissions were estimated for 54 of the 96 contaminants. Cancer unit risk factors are available for 21 of those contaminants. This enabled us to estimate the reduced cancer mortality resulting from the proposed revisions to Regulation 308 for these 21 carcinogens. Our estimates of the annual reduction in cancer mortality are shown in Exhibit 5.1.

The largest benefit occurs under Scenario B -- the most stringent controls -- and the smallest benefit occurs under Scenario C -- the least stringent controls. Under Scenario B, we estimate that annual cancer mortality would be reduced by 18 lives. Depending upon the value placed on a statistical life, this represents an annual public benefit of between $40 and $125 million. Under Scenario C annual cancer mortality would be reduced by 11 lives, representing a public benefit of between $24 and $76 million annually. Regardless of the scenario chosen, the public benefit of reduced cancer mortality due to implementation of the proposed revisions to Regulation is between $24 and $125 million.

The estimated reduction in cancer mortality for chromium is probably overstated. It was necessary to apply the cancer unit risk factor for the most virulent form -- hexavalent chromium -- to all chromium emissions thus raising the estimated reduction in cancer mortality. On the other hand, cancer unit risk factors are not available for some probable or suspected carcinogens such as ethylene dibromide, ethylene oxide and selenium so the

EXHIBIT 5.1: REDUCED ANNUAL MORTALITY BY CONTAMINANT AND SCENARIO

	Scenarios A & D	Scenario B	Scenario C	Scenario E
CANCER				
Acrylonitrile	0	0	0	0
Arsenic	7	8	6	7
Asbestos (total)	0	0	0	0
Benzene	0	0	0	0
1,3 Butadiene	1	1	1	1
Cadmium	0	0	0	0
Carbon Tetrachloride	0	0	0	0
Chloroform	0	0	0	0
Chromium	8	8	4	8
Epichlorohydrin	0	0	0	0
Ethylene Dichloride	0	0	0	0
Formaldehyde	0	0	0	0
Methylene Chloride	0	0	0	0
Nickel	0.5	0.5	0	0.5
Polychlorinate Biphenols	0	0	0	0
Propylene Oxide	0	0	0	0
Styrene	0	0	0	0
Toluene Diisocyanate	0	0	0	0
1,1,1-Trichloroethane	0	0	0	0
Trichloroethylene	0	0	0	0
Vinyl Chloride	0	0	0	0
Subtotal Cancer	17	18	11	17
NON-CANCER				
Sulphur Dioxide	250	300	97	97
Particulate Matter	50	54	25	36
TOTAL REDUCED MORTALITY	317	372	133	150
Estimated Value (million 1986 $C)				
. Low	$697.4	$818.4	$292.6	$330.0
. High	$2,203.2	$2,585.4	$924.4	$1,042.5

reduction in cancer mortality is underestimated in those instances.

Arsenic and chromium account for over 88 per cent of the reduced cancer mortality. The principal sources of emissions of these contaminants are the ferro-alloys, industrial inorganic chemicals, industrial organic chemicals and chemical products industries.

5.2.2 Non-Cancer Mortality

Exposure-response functions to estimate reduced non-cancer mortality resulting from lower contaminant emissions are available for sulphur dioxide and particulate matter. The estimated reductions in mortality due to implementation of the proposed revisions to Regulation 308 are shown in Exhibit 5.1 for each scenario. The reductions are much larger for sulphur dioxide than for particulate matter. Both are much larger than the reductions in cancer mortality.

Again the largest benefit occurs under Scenario B, while the smallest benefit occurs under Scenario C. Under Scenario C, non-cancer mortality is reduced by 122 lives per year. Depending upon the value placed upon reduced mortality, this represents an annual benefit of between $268 and $848 million. Under Scenario B, the annual reduction in non-cancer mortality is 354 lives. This represents a public benefit of between $779 and $2,460 million annually.

The total reduction in mortality from the proposed revisions to Regulation 308 is estimated to be a total of between 133 and 372 lives annually. The yearly public benefit ranges between $0.3 and $2.6 billion. Scenario B provides the greatest reduction in mortality and largest public benefit, reduced

mortality of 272 lives and, depending on the value placed on a human life, a benefit of $0.8 to $2.6 billion annually.

5.3 Other Health Benefits

5.3.1 Quantified Human Health Benefits

Exposure-response functions for non-cancer health benefits are available for sulphur dioxide and particulate matter. The estimated human health benefits resulting from reduced emissions of these contaminants are shown in Exhibit 5.2.

Again Scenario B, the most stringent, yields the greatest benefits while Scenario C, the least stringent, yields the smallest benefits. The benefits associated with reduced emissions of particulate matter are greater than those due to reduced sulphur dioxide emissions.

Under Scenario B we estimate that the annual quantifiable human health benefits from reduced concentrations of sulphur dioxide and particulate matter will be between $10 and $51 million. Under Scenario C these public benefits are estimated between $4 and $23 million.

5.3.2 Reduced Exposures to Above Standard Concentrations

The human health benefits due to reduced emissions of sulphur dioxide of particulate matter only capture a small part of the non-lethal human health benefits from more stringent control emissions proposed by the revisions to Regulation 308. Exposure-response functions have yet to be developed for the vast majority of contaminants examined in this study.

In the absence of an exposure-response function, the analysis examined the population exposed to contaminant concentrations

EXHIBIT 5.2: QUANTIFIED HUMAN HEALTH BENEFITS

	Scenarios A & D	Scenario B	Scenario C	Scenario E
Sulphur Dioxide				
Hospital Days for Respiratory Conditions	3,746	4,495	1,458	1,458
Hospital Admissions for Respiratory Disease	381	457	148	148
Value (million 1986 $C)				
. Low	$2.5	$3.0	$1.0	$1.0
. Central	$8.7	$10.4	$3.4	$3.4
Particulate Matter				
Emergency Room Visits	2,940	3,188	1,492	2,117
Restricted Activity Days	616,000	668,000	313,000	443,000
Value (million 1986 $C)				
. Low	$6.6	$7.2	$3.4	$4.7
. Central	$37.7	$40.9	$19.2	$27.1
Total (million 1986 $C)				
. Low	$9.1	$10.2	$4.4	$5.7
. Central	$46.4	$51.3	$22.6	$30.5

above the standard included in the proposed revisions to Regulation 308. In a few cases, where monitoring information was available, the analysis was based on the estimated ambient concentration from all sources. For most contaminants, however, the analysis was limited to exposures to the concentrations estimated from Regulation 308 Source emissions alone. In those cases, they underestimate the public benefits of the proposed revisions to Regulation 308.

The results are summarized in Exhibit 5.3. The figures can not be added because the toxicity of exposures to above threshold concentrations varies from one contaminant to another. It is obvious that many residents of Ontario are currently exposed to concentrations above the proposed thresholds for several contaminants. Implementation of the proposed revisions to Regulation 308 will virtually eliminate exposure to above proposed standard concentrations except for arsenic, chromium, selica, sulphur dioxide and suspended particulate matter.

The proposed revisions to Regulation 308 are effective in reducing the exposures to above proposed standard concentrations for the six contaminants where monitoring data are available. Manganese currently meets the proposed standard in the areas affected by emissions from Regulation 308 Sources. Cadmium, lead and nickel presently do not meet the proposed standard in some areas, but do meet the standard when the proposed revisions are implemented, with the exception of nickel under Scenario C. The last two contaminants -- chromium and sulphur dioxide -- do not meet the proposed standard at present or under any of the scenarios, but the number of people exposed to above threshold concentrations is reduced by the proposed revisions to Regulation 308.

These results must be qualified. The analysis is based on annual average concentrations, the dispersion of these contaminants has

EXHIBIT 5.3: POPULATION EXPOSED TO ABOVE THRESHOLD CONCENTRATIONS OF CONTAMINANTS ('000s)

	Current	Scenarios A & D	Scenario B	Scenario C	Scenario E
Arsenic	228	34	34	67	34
Cadmium*	**	-	-	-	-
Cadmium	-	-	-	-	-
Chromium*	75	26	26	34	26
Chromium	34	-	-	34	-
Ethylene Dibromide	345	-	-	-	345
Fluorides	**	-	-	-	-
Lead*	28	-	-	-	-
Lead	11	-	-	-	-
Nickel*	34	-	-	26	-
Nickel	26	-	-	-	-
Nitrogen Oxides	1	1	1	1	1
Silica	645	129	83	288	238
Sulphur Dioxide*	67	**	**	12	12
Sulphur Dioxide	12	**	**	12	12
Suspended Particulate	159	22	**	95	45

Notes: * Denotes contaminant for which population exposure is based on ambient concentration from all sources. In all other cases exposure is to concentrations due to Regulation 308 Source emissions alone.

** Population exposed is less than 500.

been modelled on the assumption that they are gases and the smallest area considered is 16 km^2. Hence exceedances in smaller areas, especially near the emission sources, and over shorter periods are not detected by the analysis.

5.4 Other Public Benefits

5.4.1 Visibility and Materials Damage

Functions to estimate the value of improved visibility and reduced materials damage are available for nitrogen oxides and particulate matter. The results, by scenario, for the proposed revisions to Regulation 308 are presented in Exhibit 5.4.

In both cases, the benefits associated with reduced emissions of nitrogen oxides are greater than those due to reduced emissions of particulate matter. The benefits estimated for improved visibility are approximately five times as large as those estimated for reduced materials damage.

The public benefits of improved visibility and reduced material damage from concentrations of nitrogen oxides and particulate matter are greatest under Scenario B; the least public benefit is derived from Scenario C. The total public benefits under Scenario B are estimated to be between $2.5 and $5.1 billion. Under Scenario C the public benefits are estimated to be between $1.5 and $3.1 billion.

It was not possible to determine additional visibility or materials damage benefits for other contaminants examined in this study due to a lack of exposure-response functions relating contaminant concentrations to improved visibility and reduced material damages.

EXHIBIT 5.4: VISIBILITY AND MATERIALS DAMAGE BENEFITS

		Scenarios A & D	Scenario B	Scenario C	Scenario E
Visibility					
Nitrogen Oxides (million 1986 C$)	Low	$1,249.0	$1,361.4	$932.5	$1,013.2
	Central	$2,560.4	$2,790.9	$1,911.6	$2,077.0
Particulate Matter (million 1986 C$)	Low	$653.2	$700.2	$328.4	$583.4
	Central	$1,306.3	$1,400.3	$656.7	$1,166.8
Total (million 1986 C$)	Low	$1,902.2	$2,061.6	$1,260.9	$1,596.6
	Central	$3,866.7	$4,191.2	$2,568.3	$3,243.8
Materials Damage					
Nitrogen Oxides (million 1986 C$)	Low	$333.2	$402.9	$234.4	$279.7
	Central	$666.3	$805.8	$468.8	$559.4
Particulate Matter (million 1986 C$)	Low	$5.8	$6.5	$2.9	$4.2
	Central	$83.0	$92.5	$42.1	$59.8
Total (million 1986 C$)	Low	$339.0	$409.4	$237.6	$283.9
	Central	$749.3	$898.3	$510.9	$619.2

5.4.2 Odour

Five of the 54 contaminants for which emissions were estimated are considered to be potential odour problems; methyl isobutyl ketone, naphthalene, propionaldehyde, styrene, and trichloroethylene. Concentrations of these five contaminants are below the proposed standards in all areas. That finding must be treated with caution, because it is based on annual average concentrations. Odour could still be a problem over shorter periods. The impact of the proposed revisions to Regulation 308 in mitigating short-term odour problems can not be determined from the available data.

5.4.3 Phytotoxicity

Only eight of the 54 contaminants for which emissions were estimated are identified as being potentially harmful to plants. These contaminants, the area under crops exposed to emissions of the contaminant by Regulation 308 Sources and the cropland exposed to above threshold concentrations of the contaminant are as follows:

	Agricultural Area Exposed (km^2)	Percent of Total Area Exposed	Area Exposed to above Threshold Concentrations (km^2)
Cadmium*	26,821	78%	0
Chlorine	6,171	18%	0
Ethylene	25,353	75%	0
Fluorides	24,982	73%	0
Hydrogen Chloride	2,863	8%	0
Nickel*	26,736	78%	0
Selenium	25,689	75%	0
Sulphur Dioxide*	18,438	54%	0

* The calculated exposures include the maximum contribution of non-Regulation 308 Sources as estimated from monitoring data.

The agricultural areas exposed to emissions of these contaminants from Regulation 308 Sources are relatively large. However, no areas are exposed to concentrations in excess of the proposed standards for these contaminants due to emissions from Regulation 308 Sources alone. Hence, the public benefits in the form of reduced damage to crops and forests resulting from the proposed revisions to Regulation 308 are likely to be small and possibly negligible.

5.5 Aggregate Economic Valuation

The estimated values of reduced mortality, non-lethal health benefits, lower materials damage and improved visibility resulting from implementation of the proposed revisions to Regulation 308 are summarized in Exhibit 5.5.

These figures apply ONLY to those FEW cases where the public benefits can be quantified and the associated economic values can be estimated. The absence of a damage function or even emissions data for a contaminant does not mean that there is no benefit to be had by regulating emissions of that contaminant. Given the limited range of contaminants and benefits that can be quantified and valued, the figures in Exhibit 5.5 must be considered minimum estimates of the benefits associated with the proposed revisions to Regulation 308.

In the low case, the annual benefits range from $1.8 to $3.3 billion and are predominantly attributable to improved visibility. In the central case, the annual benefits range from $4.0 to $7.7 billion. The health benefits represent approximately 25 to 35 per cent of the total in the central case.

Results from a study conducted for the California Air Resources Board showed that between 62 to 68 per cent of the benefits of air pollution control were due to human health, while between 12

EXHIBIT 5.5: AGGREGATE AMOUNT OF BENEFITS TO WHICH AN ECONOMIC VALUE HAS BEEN ASSIGNED
(Millions of 1986 $C Annually)

	Scenarios A & D	Scenario B	Scenario C	Scenario E
Low Case				
Reduced Mortality	$695.2	$816.2	$290.4	$327.8
Non-Lethal Health Benefits	$9.1	$10.2	$4.4	$5.7
Lower Materials Damage	$339.0	$409.4	$237.6	$283.9
Improved Visibility	$1,902.2	$2,061.6	$1,260.9	$1,596.6
Total	$2,945.5	$3,297.4	$1,793.3	$2,214.0
Central Case				
Reduced Mortality	$2,196.2	$2,578.5	$917.4	$1,035.6
Non-Lethal Health Benefits	$46.4	$51.3	$22.6	$30.5
Lower Materials Damage	$749.3	$898.3	$510.9	$619.2
Improved Visibility	$3,866.7	$4,191.2	$2,568.3	$3,243.8
Total	$6,858.6	$7,719.3	$4,019.2	$4,929.1

and 30 per cent were due to materials damage and between 8 and 25 per cent were due to changes in visibility. Less than 1 per cent of the benefits were due to reduced crop and forest damage.

The differences with this study are due, in part, to differences in the contaminants considered. The California study included ozone and major sources of sulphate and particulate emissions that were excluded from this study because they are governed by the acid rain initiative. The Santa Clara and Denver Integrated Environmental Management Projects found that sulfate aerosol air pollution was the most significant cause of human morbidity and mortality among the air pollutants examined. This indicates that contaminant coverage can have a major impact on the composition of the benefits.

5.6 Other Findings

Our analysis of the public benefits of the proposed revisions to Regulation 308, despite indicating significant benefits overall, raises some questions concerning specific aspects of those proposals. Specifically,

- The fact that no emissions were found for over one-third of the contaminants is slightly troubling. They might not be emitted by Ontario industry. Or the emissions might be so small as to fall under the de minimis provisions of the proposal. Or the process of speciating the PM and VOC emissions may have inadvertently excluded them. A better understanding of the situation with respect to those contaminants would be reassuring.

- The ambient air quality standards that form part of the proposed revisions to Regulation 308 are in many instances less stringent than comparable standards in American states.

This can be seen in Appendix C. In the case of trichloroethylene for example, ambient air quality standards are available for 11 states, and all but one of those standards is more stringent than the 28,000 micrograms per cubic metre averaged over 24 hours in the proposed revisions to Regulation 308. In some of those states the standard is lower by a factor of 1,000. A review of the proposed standards in relation to those used in the United States may be warranted.

- For a few contaminants, it appears that the proposed requirements relating to control technologies will not result in achievement of the ambient air quality standard suggested in the revisions to Regulation 308. For example, arsenic, suspended particulate and sulphur dioxide concentrations due to emissions from Regulation 308 Sources exceed the proposed standards in significant areas even under the most stringent scenario. Nitrogen oxide exceedances are not affected by the proposed revisions to Regulation 308. Ambient standards that can not be achieved even with the best technology available are of dubious value.

- The largest gaps in our knowledge appear to be at the start and end of the analytical process used in this study. The analysis starts with data on the quantity, composition and temporal pattern of contaminant emissions by each source. At present these are unknowns. The proposed provisions with respect to monitoring, if implemented, will help fill this void.

Our knowledge of the effects of specific ambient concentrations of contaminants on human health or other resources is very uncertain. The determination of the public benefits of reduced ambient concentrations is equally

uncertain. Research on the effects of contaminant concentrations is an immense task; fortunately it need not be specific to Ontario to be of value here.

5.7 Suggested Refinements

We have stressed repeatedly that the analysis reported here is very broad in scope. It is a pioneering study in terms of the scope of its analysis. Not surprisingly then, a number of improvements are possible.

- The analysis is based on estimated emissions by identified sources. More accurate data on the composition and quantities of specific contaminants emitted by specific sources would be a major improvement. The methods used in this study allow actual emissions data to replace the estimated emissions for any source. Thus incremental improvements can be made as data become available. Comprehensive emission data are not needed to get better results.

  It is our understanding that boiler emissions were excluded from the estimates for most sectors. Boiler emissions can be significant sources of many PM and VOC contaminants. The inclusion of boiler emissions would be a relatively simple, but significant, extension of the analysis.

- The emissions of a contaminant from non-Regulation 308 Sources is another major data gap. Monitoring data must be used for this purpose. The value of the available monitoring data was limited. Many of the contaminants analysed are VOC's. The monitoring data do not indicate the mix of chemicals that make up the VOC's detected.

The northeast corridor study performed by the U.S. EPA suggests that approximately 50 per cent of total VOC emissions are due to area, not point, sources. Thus, the non-Regulation 308 VOC emissions are likely to be a significant part of the total and they could have a significantly different composition than the emissions from the Regulation 308 Sources studied.

Analysis of the composition of the VOC's monitored would permit the analysis applied to cadmium, chromium, lead, manganese, nickel and sulphur dioxide to be extended to all VOC's. In other words, the effect of the proposed revisions to Regulation 308 on ambient concentrations due to all emission sources could be assessed.

- Focusing on a smaller geographic area would allow more detailed analysis of the study area. A smaller geographic area would allow the use of a finer grid (e.g., 2 km), more accurate location of sources, and more accurate determination of the resources affected by Regulation 308 Source emissions. The area(s) selected for detailed analysis could be the area(s) of greatest interest for each contaminant as determined by this study.

- Consideration of the variability of emissions over the course of a year rather than simply the annual average. This allows the hours of operation of establishments to be considered. Fluctuations in emissions during operating hours could be simulated. Then threshold exceedances over shorter periods could be analysed. Odour reduction benefits can only be addressed properly in this context.

This would not enhance the analysis of human health effects significantly. Scientific knowledge of the human health effects of exposures to the various contaminants is quite

limited in most cases. Only in a few cases would it be possible to set different standards for different averaging times, such as one hour, 24 hours and one year. For the vast majority of contaminants a single standard would be converted to an equivalent standards for the other averaging times. Thus, the human health analysis would gain little from the detailed treatment of variations in emissions.

- The output of models of ozone formation, and long range transport of air pollutants can be readily added to the analysis presented above. The only requirement is the ability to express those outputs as annual average ambient concentrations over specified areas. Similarly, regulations such as the acid rain initiative could be incorporated into the analysis to get a more complete picture of air pollution in Ontario, and the most effective means of regulating contaminants.

EXHIBIT 2.2: LIST OF 96 REGULATION 308 CONTAMINANTS REFERRED TO IN THIS STUDY

Acrylonitrile
Ammonia
Arsenic
Arsine
Asbestos (Fibers of length greater than 5 micrometers)
Asbestos (Total)
Benzene
Benzo(a)pyrene
Beryllium
2-Butanone (Methyl Ethyl Ketone)
Butyl Acrylate
Cadmium
Calcium Cyanide (As total salt)
Captan
Carbon Tetrachloride
Chlordane
Chlorinated Dibenzo Dioxins (CDDs)
Mixtures of Chlorinated Dibenzo Dioxins and Chlorinated Dibenzo Furans (CDFs)
Chlorine
Chlorine Dioxide
Chloroform
Chromium
Coal Tar Pitch Volatiles (Soluble fraction)
Chromium (Di, Tri, and Hexavalent forms)
Epichlorohydrin
Ethyl Benzene
Ethylene
Ethylene Dibromide
Ethylene Dichloride
Ethylene Glycol Butyl Ether (Butyl Cellosolve)
Ethylene Glycol Butyl Ether Acetate (Butyl Cellosolve Acetate)
Ethylene Glycol Ethyl Ether (Cellosolve)
Ethylene Gylcol Ethyl Ether Acetate (Cellosolve Acetate)
Ethylene Oxide
Fluorides
Formaldehyde
Hexachlorocyclopentadiene
Hydrogen Chloride
Hydrogen Cyanide
Hydrogen Sulphide
Inhalalable Particulates (Less than 10 micrograms)
Lead
Manganese Compounds
Mercaptans
Mercury
Mercury (Alkyl)
Methane Diphenyl Diisocyanate

Methyl Isobutyl Ketone
Methylene Chloride
4,4-Methylene-bis-2-chlorol-aniline
Naphthalene
Nickel
Nickel Carbonyl
Nitrogen Oxides
Nitrous Oxide
Ozone
Pentachlorobenzenes
Pentachlorophenol
Perchloroethylene
Phenol
Phosgene
Phosphine
Polychlorinated Biphenyls (PCB's)
Polycyclic Aromatic Hydrocarbons (PAH's)
Potassium Cyanide (As total salt)
Potassium Hydroxide
Propionaldehyde
Propionic Acid
Propylene Glycol Methyl Ether
Propylene Glycol Monomethyl Ether Acetate
Propylene Oxide
Selenium
Silica-respirable (Less than 10 micrometres in diameter)
Sodium Cyanide (As total salt)
Sodium Hydroxide
Styrene
Sulphur Dioxide
Sulphuric Acid
Suspended Particulate Matter (Less than 44 microns in size)
Tetrachlorobenzenes
Tetrachlorophenols
Thiourea
Tin
Toluene
Toluene Diisocyanate
Total Reduced Sulphur (TRS)
1,2,4-Trichlorobenzene
1,1,1-Trichloroethane (Methyl Chloroform)
Trichlorobenzenes
Trichloroethylene
Tricholorophenols
Vinyl Chloride
Xylenes
1,3 Butadiene*
Polycyclic organic matter*
Trichromium*

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* Added during the course of the study

EXHIBIT 2.3: LIST OF SECTORS COVERED

	Plants	Employees
Mining Industries		
0611 Gold Mines (open pit only)	4	1210
0617 Iron Mines (open pit only)	2	700
Food Industries		
1011 Meat and Meat Products Industry	114	8077
1012 Poultry Products Industry	32	
1021 Fish Products Industry	17	551
1049 Other Dairy Products Industries (Whey drying only)	7	1117
Paper and Allied Products Industries		
2711 Pulp Industry	9	7209
2712 Newsprint Industry	11	6189
2713 Paperboard Industry	16	2737
Printing, Publishing and Allied Industries		
2811 Business Forms Printing Industry	44	4228
2819 Other Commercial Printing Industries	356	23601
2821 Platemaking, Typesetting and Bindery Industry	129	6133
2841 Newspaper, Magazine and Periodical (Combined Publishing and Printing) Industry	81	12205
2849 Other Combined Publishing and Printing Industries	11	528
Iron and Steel Industries		
2911 Ferro-Alloys Industry	1	16
2912 Steel Foundries	22	39009
2919 Other Primary Steel Industries	35	2205
Foundries		
2941 Iron Foundries	61	7110
2959 Other Primary Smelting and Refining of Non-Ferrous Metal Industries	15	7761
2971 Copper and Copper Alloy Rolling, Casting and Extruding Industry	23	2149
2999 Other Rolled, Cast and Extruded Non-Ferrous Metal Products Industries	63	5623

EXHIBIT 2.3: LIST OF SECTORS COVERED (Continued)

Automobile and Automotive Parts		
3231 Motor Vehicle and Parts Industries (Painting activities only)	212	125769
3254 Motor Vehicle Steering and Suspension Parts Industry	32	7106
3255 Motor Vehicle Wheel and Brake Industry (Brake lining & aluminum wheel plants only)	6	1570
3259 Other Motor Vehicle Accessories, Parts and Assemblies Industries (Batteries only)	5	548
Non-Metallic Mineral Products Industries		
3511 Clay Products Industry (From Domestic Clay)	26	1405
3512 Clay Products Industry (From Imported Clay)	51	1187
3521 Hydraulic Cement Industry	8	2092
3571 Abrasives Industry	25	1906
3581 Lime Industry	9	885
Refined Petroleum Products Industries		
3611 Refined Petroleum Products Industry	7	3810
Asphalt Paving Plants		
3699 Other Petroleum and Coal Products Industries (Portable asphalt paving plants)	24	
Inorganic Chemical Products Industries		
3711 Industrial Inorganic Chemical Industries n.e.c.	67	7905
Organic Chemical Products Industries		
3712 Industrial Organic Chemical Industries n.e.c.	37	7114
3721 Chemical Fertilizer and Fertilizer Materials Industry	13	1279
3731 Plastic and Synthetic Resin Industry	80	5539
3751 Paint and Varnish Industry	98	6185
3791 Printing Ink Industry	40	1693
3792 Adhesives Industry	43	1469
3799 Other Chemical Products Industries n.e.c.	188	9891
Electric Power Generation		
4911 Electric Power Systems Industry (Fossil fuel fired stations only)	6	

EXHIBIT 2.3: LIST OF SECTORS COVERED (Continued)

Waste Disposal	
4999 Municipal Landfills	47
4999 Municipal and Commercial Incinerators	3
4999 Sewage Sludge Incinerators	5
4999 Hospital Incinerators	100
Restaurants	
9211-9213 Restaurants, (Charcoal barbecue restaurants only)	200
Dry Cleaners	
9721 Power Laundries and/or Dry Cleaners	1200

EXHIBIT 3.4: CONTAMINANTS' EFFECTS ON VARIOUS ASPECTS OF THE ENVIRONMENT

Chemical	Cancer	Non-Cancer	Animal Effects	Phyto-toxicity	Aquatic Ecosystem	Surface Water	Visibility	Odour	Materials Damage
Acrylonitrile (107-13-1)	Q	K	Q	K	U	U	U	Q	U
Ammonia (7664-41-7)	U	K	Q	U	U	U	U	Q	U
Arsenic (7440-38-2)	Q	Q	Q	K	U	U	U	U	U
Arsine (7784-42-1)	U	Q	Q	U	U	U	K	Q	U
Asbestos (1332-21-4)	Q	K	Q	U	U	U	U	U	U
Benzene (71-43-2)	Q	Q	Q	U	K	U	K	Q	U
Benzo[a]pyrene (50-32-8)	K	U	K	U	U	U	U	U	U
Beryllium (7440-41-7)	Q	Q	Q	U	U	U	U	U	U
1,3-Butadiene (106-99-0)	Q	Q	Q	U	U	U	U	K	U
2-Butanone (78-93-3)	U	Q	Q	U	U	U	K	Q	U
Butyl Acrylate (141-32-2)	U	K	Q	U	U	U	U	Q	U
Cadmium (7440-43-9)	Q	Q	Q	K	U	K	U	U	U
Calcium Cyanide (592-01-8)	U	Q	Q	U	U	U	U	U	U
Captan (133-06-2)	S	Q	Q	U	U	U	U	U	U
Carbon Tetrachloride (56-23-5)	Q	Q	Q	U	U	U	U	Q	U
Chlordane (57-74-9)	Q	Q	Q	U	U	U	U	U	U
Chlorine (7782-50-5)	U	Q	Q	K	U	U	K	Q	U
Chlorine Dioxide (10049-04-4)	U	Q	Q	U	U	U	U	Q	U
Chloroform (67-66-3)	Q	Q	Q	K	K	U	U	Q	U
Chromium (7440-47-3)	Q	Q	Q	K	K	U	U	Q	U
Coal Tar Pitch Volatiles (8007-45-2)	K	U	Q	U	U	U	U	U	U
Epichlorohydrin (106-89-8)	Q	Q	Q	U	U	U	U	Q	U
Ethylene (74-85-1)	U	U	Q	K	U	U	U	U	U
Ethyl Benzene (100-41-4)	U	Q	Q	U	U	U	U	Q	U
Ethylene Dibromide (106-93-4)	S	Q	Q	U	K	U	U	Q	U
Ethylene Glycol Butyl Ether (107-21-1)	U	Q	Q	U	U	U	U	Q	U

EXHIBIT 3.4: CONTAMINANTS' EFFECTS ON VARIOUS ASPECTS OF THE ENVIRONMENT (Continued)

Chemical	Cancer	Non-Cancer	Animal Effects	Phyto-toxicity	Aquatic Ecosystem	Surface Water	Visibility	Odour	Materials Damage
Ethylene Glycol Butyl Ether Acetate	U	U	Q	U	U	U	U	Q	U
Ethylene Glycol Ethyl Ether	U	K	Q	U	U	U	U	U	U
Ethylene Glycol Ethyl Ether Acetate	U	S	Q	U	U	U	U	U	U
Ethylene Dichloride (107-06-2)	Q	Q	Q	U	U	U	U	Q	U
Ethylene Oxide 75-21-08)	S	K	Q	U	U	U	U	Q	U
Fluorides Total (16984-48-8)	U	K	Q	Q	U	U	U	U	U
Formaldehyde (50-00-0)	Q	Q	Q	S	U	U	K	Q	U
Hexachlorocyclopentadiene (77-47-4)	U	Q	Q	U	U	U	U	Q	U
Hydrogen Chloride (7647-01-0)	U	K	Q	U	U	U	U	Q	K
Hydrogen Cyanide (74-90-8)	U	Q	Q	U	U	U	U	Q	U
Hydrogen Sulphide (7783-06-4)	U	Q	Q	U	U	U	U	Q	U
Inhalable Particulates less than 10 ug [A]	U	Q	Q	U	U	U	Q	U	K
Lead [A] (7439-92-1)	U	Q	Q	U	U	U	U	U	U
Manganese (7439-96-5)	U	K	Q	U	U	U	U	U	U
Mercaptans	U	U	Q	U	U	U	U	Q	U
Mercury (7439-97-6)	U	K	Q	U	U	U	U	U	U
Mercury-Alkyl (7439-97-6)	U	K	Q	U	U	U	U	U	U
Methane Diphenyl Di-Isocyanate	U	U	Q	U	U	U	U	U	U
Methyl Isobutyl Ketone (108-10-1)	U	Q	Q	U	U	U	U	Q	U
Methylene Chloride (75-09-2)	Q	Q	Q	K	K	U	U	Q	U
Napthalene (91-20-3)	U	K	Q	U	U	U	U	Q	U

EXHIBIT 3.4: CONTAMINANTS' EFFECTS ON VARIOUS ASPECTS OF THE ENVIRONMENT (Continued)

Chemical	Cancer	Non-Cancer	Animal Effects	Phyto-toxicity	Aquatic Ecosystem	Surface Water	Visibility	Odour	Materials Damage
Nickel (7440-02-0)	Q	Q	Q	K	U	U	U	U	U
Nickel Carbonyl (13463-39-3)	K	K	Q	U	U	U	U	Q	U
Nitrogen Dioxide [A] (10102-44-0)	U	Q	Q	U	U	U	U	U	U
Nitrous Oxide (10024-97-2)	U	Q	Q	U	U	U	U	U	U
Ozone [A] (10028-15-6)	U	Q	Q	Q	U	U	U	Q	K
Pentachlorobenzene (608-93-5)	U	Q	Q	U	U	U	U	Q	U
Pentachlorophenol (87-86-5)	U	Q	Q	K	K	U	U	U	U
Perchloroethylene (127-18-4)	U	Q	Q	U	U	U	U	Q	U
Phenol (108-95-2)	U	Q	Q	K	K	U	U	Q	K
Phosgene (75-44-5)	U	K	Q	U	U	U	U	Q	U
Phosphine (7803-51-2)	U	Q	Q	U	U	U	U	Q	U
Polychlorinated Biphenyls (1336-36-3)	Q	K	Q	U	U	U	U	U	U
Potassium Cyanide (151-50-8)	U	Q	Q	U	U	U	U	U	U
Potassium Hydroxide (1310-58-3)	U	K	Q	U	U	U	U	U	U
Propionaldehyde	U	U	Q	U	U	U	U	Q	U
Propionic Acid (79-09-4)	U	K	Q	U	U	U	U	Q	U
Propylene Glycol Monomethyl Ether (107-98-2)	U	K	Q	U	U	U	U	Q	U
Propylene Glycol Monomethyl Ether Acetate (108-65-6)	U	K	Q	U	U	U	U	Q	U
Propylene Oxide (75-56-9)	Q	K	Q	U	U	U	U	U	U
Selenium (7782-49-2)	S	K	Q	K	K	U	U	U	U
Silica	U	K	Q	U	U	U	U	U	U
Sodium Cyanide (143-33-9)	U	Q	Q	U	U	U	U	U	U
Sodium Hydroxide (1310-73-2)	U	K	Q	U	U	U	U	U	K

EXHIBIT 3.4: CONTAMINANTS' EFFECTS ON VARIOUS ASPECTS OF THE ENVIRONMENT (Continued)

Chemical	Cancer	Non-Cancer	Animal Effects	Phyto-toxicity	Aquatic Ecosystem	Surface Water	Visibility	Odour	Materials Damage
Styrene (100-42-5)	Q	Q	Q	U	K	U	U	Q	U
Sulfur Dioxide [A] (7446-09-5)	U	Q	Q	Q	U	U	U	Q	K
Sulfuric Acid (7664-93-9)	U	K	Q	U	U	U	U	U	K
Suspended Particulate Matter less than 44 um [A]	U	Q	Q	U	U	U	K	U	K
Tetrachlorobenzene (95-94-3)	U	Q	Q	K	K	U	U	U	U
Tetrachlorophenols (58-90-2)	U	Q	Q	U	U	U	U	U	U
2,3,7,8-Tetrachloro-dibenzo-p-dioxin (1746-01-6)	S	Q	K	U	U	U	U	U	U
Thiourea (62-56-6)	U	U	U	U	U	U	U	U	U
Tin (7440-31-5)	U	K	Q	U	U	U	U	U	U
Toluene (108-88-3)	U	Q	Q	U	U	U	U	Q	U
Toluene Diisocyanate (584-84-9)	Q	K	Q	U	U	U	U	Q	U
Total Reduced Sulfur	U	U	Q	U	U	U	U	U	U
1,2,4-Trichlorobenzene (120-82-1)	U	Q	Q	U	U	U	U	Q	U
1,1,1-Trichloroethane (71-55-6)	U	Q	Q	U	U	U	U	U	U
1,3,5-Trichlorobenzene (108-70-3)	U	K	Q	U	U	U	U	U	U
Trichloroethylene (79-01-6)	Q	Q	Q	U	K	U	U	Q	U
2,4,6-Trichlorophenol (88-96-2)	Q	U	Q	U	U	U	U	Q	U
Vinyl Chloride (75-01-4)	Q	Q	Q	U	U	U	U	Q	U
Xylenes (1330-20-7)	U	Q	Q	K	K	U	U	Q	U

Q - Known and quantified effect
K - Known and unquantified effect
S - Suspected and unquantified effect
U - Unknown effect